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Materials & Methods

May
1953

How Economic Factors Influence Materials Selection

A New Corrosion Resistant Alloy

Vacuum Formed Thermoplastics for Large, Thin Parts

Electroless Plating—Where It Stands Today

Selecting Materials for Small Assemblies

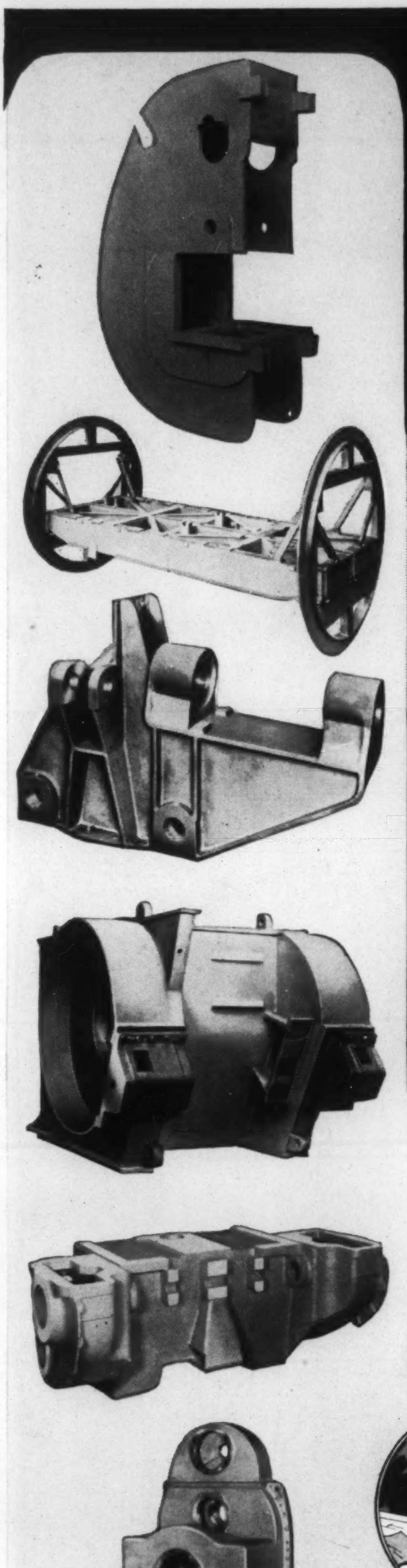
Two New Synthetic Rubbers

Chromizing Improves Surface Properties of Steels

New Developments in Zirconium

WELDING THE STAINLESS STEELS
—Materials & Methods Manual No. 94

THE MAGAZINE OF
MATERIALS ENGINEERING
DEVOTED TO THE MATERIALS PROBLEMS OF PRODUCT DESIGN AND MANUFACTURE



Steel-Weld

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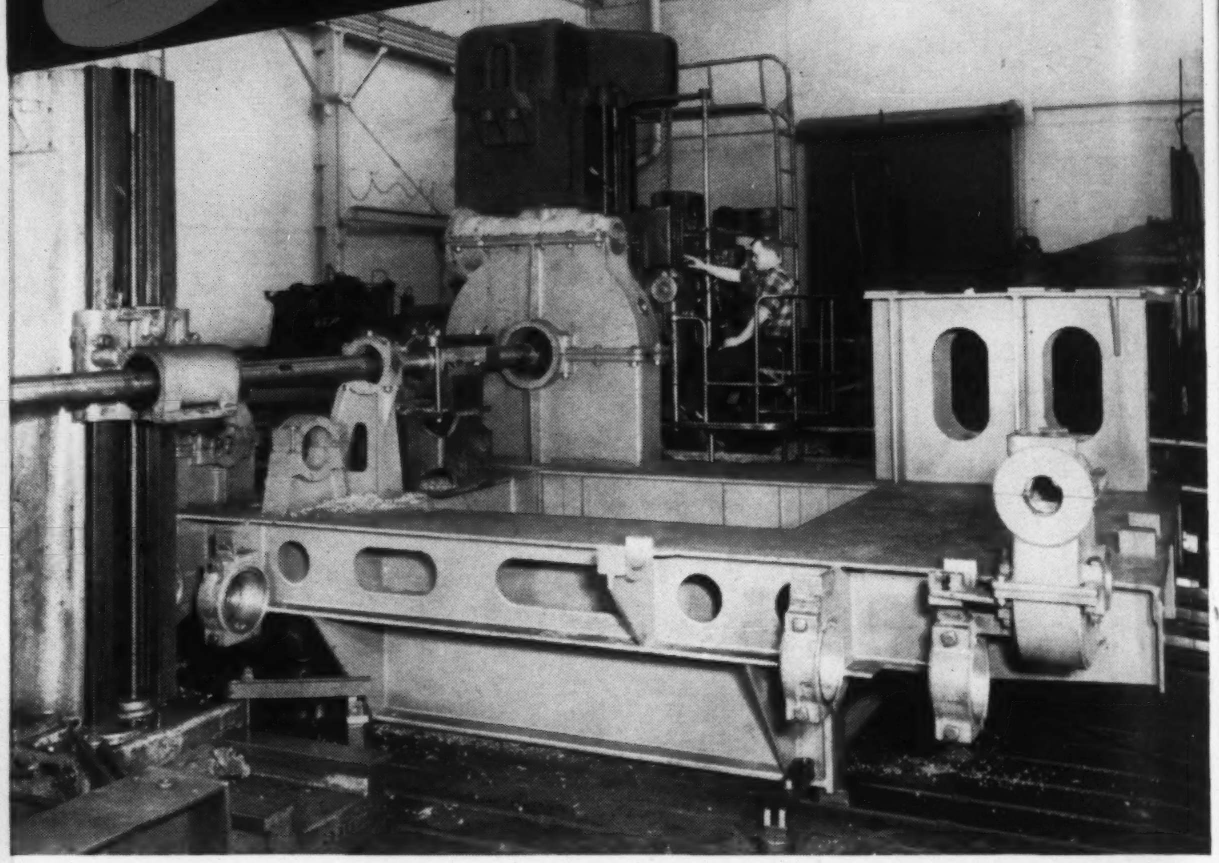

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The Materials Outlook

A silicon nitride having excellent oxidation resistance up to 2190 F and subject to only minor oxidation up to 2550 F has been developed. Designed for rocket nozzle inserts, the compound contains no bonding element, traditionally the weak link in a nonmetallic high temperature material. . . . A similar approach was taken in developing a new ceramic coating for metals that withstands temperatures up to 3000 F. It also is a two-phase material, with bonding being achieved by "complex structural combination akin to solid solution." Because of its extremely low porosity, it can be used effectively in thicknesses from ½ to 1 mil. Cost is said to be comparable to present enamels.

A little rosier copper picture here may result from lagging demand in Europe. Some of the output of Rhodesia and the Belgian Congo is now finding its way to the U. S. Imports from these sources may run as high as 5000 to 10,000 tons a month in the third quarter. Domestic copper price may be forced down.

A new vinyl coating system for chemical industry paint applications is claimed to bypass traditional problems of poor adhesion and low build. Key to the system is a high-build drying oil primer which drys to a 2 mil thickness and, by its greater edge build, reduces total paint thicknesses needed from usual 5 or 6 mils to only 4.

Glass-reinforced Teflon pipe capable of handling pressures up to 500 psi or more is being developed for the chemical industry. Metal-backed Teflon fittings may be used. In one trial the pipe was used to bubble organics into hydrofluoric acid.

A rivet said to make "blind" sections as easy to handle as open ones and to be less costly than others on the market is being introduced in this country after many years use in England. Available in monel and aluminum, they do not require skilled operators for use.

Plenty of carbon and graphite to go around is the outlook at least for the next two years. Upon completion of current expansion programs in 1954, production capacity and expected demand for carbon will be about in balance, and graphite capacity is expected to exceed demand by 5 to 10%.

This year's stepped-up government stockpiling of aluminum may offset the improvement in supply that was expected to result from current expansion programs, the aluminum industry says. . . . More aluminum in auto-

(Continued on page 4)

The Materials Outlook *(continued)*

mobiles seems a certainty. Aluminum radiators are being seriously studied. One manufacturer is said to be considering a die-cast aluminum six-cylinder engine block.

The rare earths, which are metals and not too rare, are assuming more importance all the time. Magnesium-thorium-zinc-zirconium alloys have extended the usefulness of magnesium castings to 600 F, making possible the retention of the lighter metal in structural members where increasing operating temperatures were expected to make necessary a switch to another metal. . . . Small additions of misch metal improve the fluidity and machinability of stainless steels. Although extensive use of the cerium alloy for this purpose will have to wait for lower cost, a price reduction may not be far off.

Tougher and cheaper GR-S cold rubber is claimed as a result of a new process. Improvement is attributed to more thorough mixing of the latex with carbon black. Tires made of the new form of synthetic are claimed to last 20% longer than those of conventional GR-S.

A low-viscosity form of cellulose acetate butyrate has been developed for protective coatings for metals. The lacquer is claimed to have much greater resistance to weathering than cellulose nitrate and to be far less flammable. The developers say it does not blister or peel in underwater immersion as does nitrate.

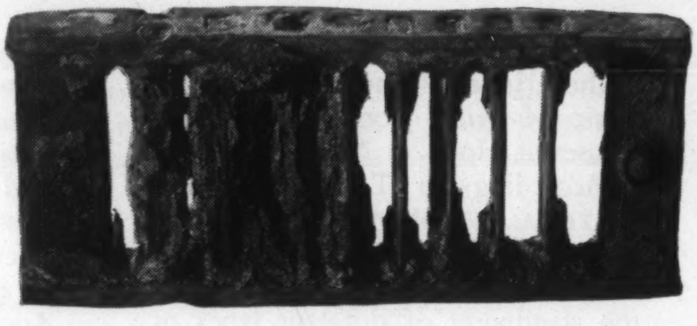
A strong trend away from high-alloy metals toward low-alloy and low-carbon steels protected by ceramic coatings is underway for many high temperature applications, especially in jet engines. In many cases the trend has been forced by the need for conservation of critical alloying elements, but improved engineering properties have also resulted from many such changes. Difficulty in developing coatings that will withstand prolonged high temperatures and abrasive conditions is an important limiting factor in this trend.

A marked slash in the time required for radiographic inspection of castings or precision assemblies is expected to result from work now being done to adapt the famous Polaroid-Land camera to x-ray photography. Time from exposure to finished dry print will be about 2 min.; no chemicals or darkroom needed.

A flexible polystyrene film, originally made in Germany, is being produced here in the form of tape for use in high frequency applications. It is said to resist large compressive forces up to 200 F and to be unaffected by adverse humidity conditions. It is now being used as insulation for coaxial cable.

Rhenium, now astronomical in cost, is getting a lot of attention in the laboratory as a potential metal for electronic applications. With sufficient demand, rhenium would be more readily available and cost less than platinum and platinum group metals.

Here are before and after photos of test racks of different alloys. The "after" photo (below) shows how the alloys react with exposure to high-temperature corrosion in tests. It's through tests like this that Inco's High-Temperature Corrosion Engineers are able to determine the material to recommend for special operating conditions.



What's Your High-Temperature Problem?

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MATERIALS ENGINEERING **News Digest**

Special Panels Scheduled for June Materials Conference

Also: Eric Hodgins on the Paley Report

How to coordinate materials, design, production and sales will be the topic of a special panel to be held June 18, the last day of the Basic Materials Conference, at the Roosevelt Hotel in New York City.

According to T. C. DuMond, MATERIALS & METHODS Editor and chairman of the conference, this subject will be approached from the standpoint of different types of industries, with the problems of both large and small fabricators receiving attention.

Light and Strong

Another panel to be held on the opening day, June 16, will cover light-weight, high-strength materials. Of particular interest to the transportation field, the materials discussed will range from low-alloy, high-strength steels to reinforced plastics, including titanium, aluminum and magnesium.

Another feature of the opening session will be a talk by Eric Hodgins, a member of the board of editors of *Fortune,* and generally credited with the writing of major portions of the so-called Paley Report. Purpose of his talk is to show industry how it can use to advantage the information contained in that report.

Materials Show

The Basic Materials Conference will run from Tuesday, June 16, to Thursday, June 18. Held concurrently will be the Basic Materials Exposition in Grand Central Palace, opening Monday, June 15, and closing Friday, June 19. Together, the conference and exposition represent the first technical show ever devoted to engineering materials as a whole, rather than specific materials or types of materials.

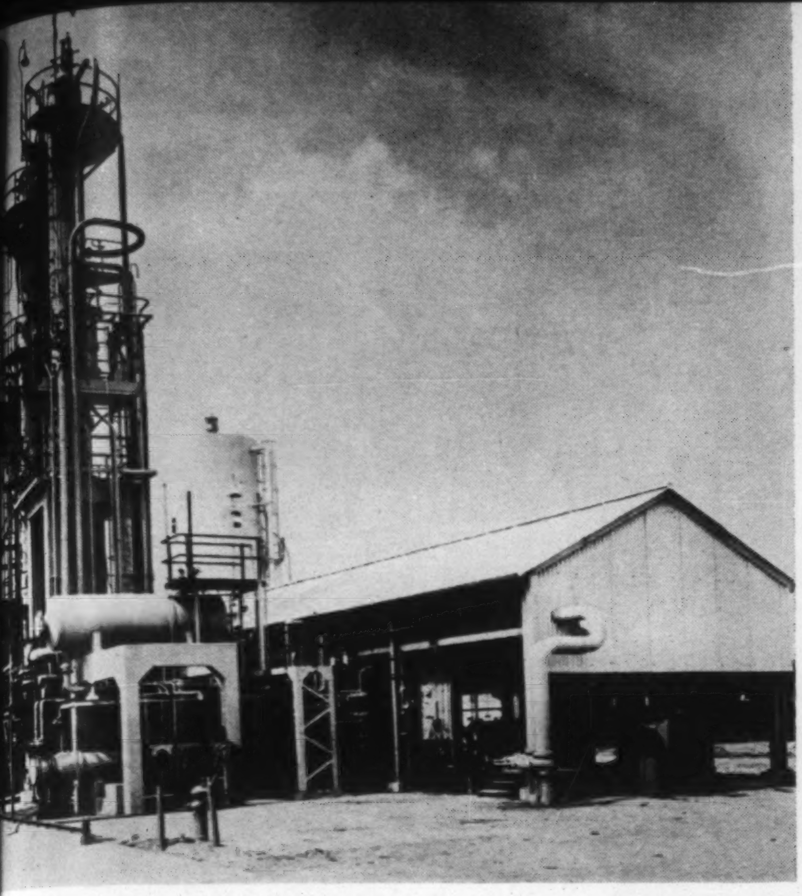
The complete technical program for the conference and a guide for the exposition will be given in the next issue of this magazine, which will be published at the beginning of June.

Advance registration cards for the conference can be obtained from Clapp & Poliak, Inc., 341 Madison Ave., New York 17.

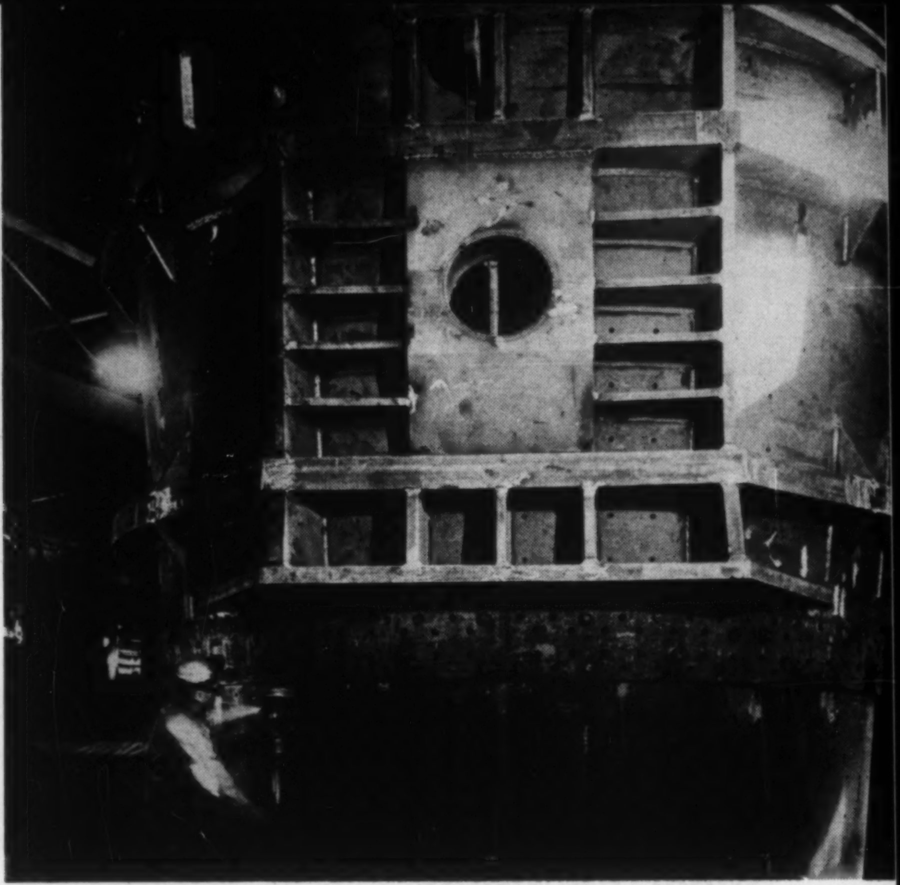
Mortar Shells While alleged ammunition shortages hold public attention, production of shells proceeds at a fast clip. The 4.2 mortar shell being inspected here started out as high-carbon, high-manganese seamless mechanical tubing produced by Pittsburgh Steel Co. and was then fabricated by Lehigh Foundries, Inc. Before being packed for shipment, it will be cleaned, bonderized and painted with a fine coat to prevent corrosion.

Copper

Consumption of refined copper and copper scrap in the United States totalled 2,188,000 short tons (copper content) last year, according to figures released by the National Production Authority. Supply, including both home consumption and exports, amounted to 2,529,000 tons.



More Epoxy Resins From this enlarged plant of Shell Chemical Corp. will come an increased supply of epichlorohydrin—a major component of epoxy resins. Next fall, Shell will put into operation the world's largest epoxy resin plant in Houston.



Mammoth Steel Ladle of 265-ton capacity will be installed in the Sparrows Point, Md., plant of Bethlehem Steel Co. First of 18 such open hearth ladles, it stands 16 ft high and weighs 44 tons. Here it is being stress-relieved after welding.

Magnesium Industry Puts on Big Show

But Attendance Not Too Large

"Something about magnesium—whatever *that* is."

So the cop on the beat summed up what was going on a few feet away in Washington's National Guard Armory last month.

There is no doubt that magnesium has grown so fast that it has taken most of the American public by surprise. Even with lots of publicity, the First International Magnesium Exposition was able to attract only half of the 50,000 visitors it expected.

But Industry Knows

The manufacturing industries, however, are becoming increasingly aware of the possibilities of the metal often billed as "the only metal in unlimited supply". As a result of their demand, together with military needs, annual magnesium production has jumped from 20,000 tons to 105,000 tons in the last two years. According to the Paley Report, consumption will be about 376,000 tons in 1975.

Another measure of the growth of magnesium is the short history of the Magnesium Assn. It was formed nine years ago by a handful of companies for the purpose of exchanging information on manufacturing techniques, development of new alloys, protective finishes and new applications. Today it has 47 members, including several in Canada, England, Norway, Sweden and France.

Despite the variety of present-day civilian uses for magnesium, the bulk of the growth in the industry is due to military applications. The first all-magnesium show was an at-

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ASTM Shaping New 'Specs'

Several new specifications for engineering materials and for methods of testing them began to take on shape during the annual ASTM Committee Week held in March at Detroit.

Among the items discussed:

1. Specifications for nodular irons at strength levels of 60,000, 90,000 and 120,000 psi. These values are far beyond the range of gray cast irons now standardized.
2. Three specifications based on use of extra low-carbon grades of Types 304 and 316 stainless steel.
3. Development of recommended practices for conducting fatigue tests according to accepted statistical methods.
4. Publication of reference radiographs for aluminum and magnesium castings. These have been made available to ASTM by the Navy's Bureau of Aeronautics and are expected to be printed this year.
5. Improving the reproducibility and broadening the applicability of the controversial salt spray test.
6. Specifications for standard struc-

(Continued on page 8)

News Digest

tural aluminum shapes and for aluminum fasteners.

7. Upcoming tests of electroplated tin coatings on steel and copper, as well as coatings of tin alloyed with zinc, lead, cadmium, copper and nickel.

8. Impact properties of malleable iron. Excellent retention of impact properties at both elevated and subzero temperatures was reported to Committee A-7.

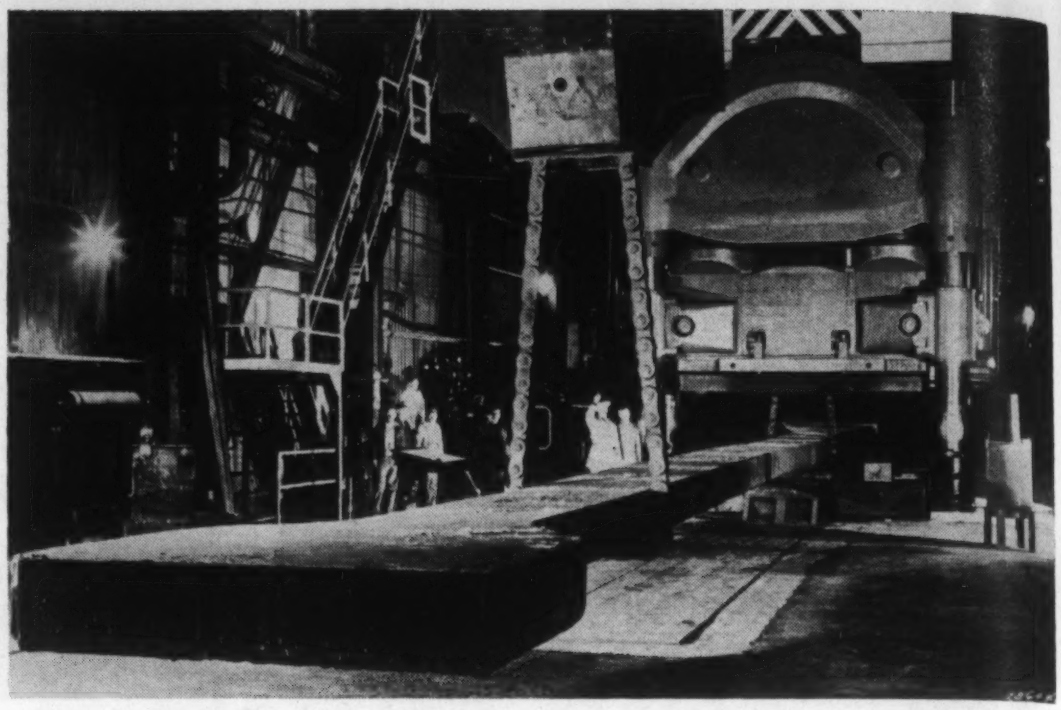
Sheet Fastener

Two pieces of sheet metal can be fastened together without rivets by means of a new technique similar to that often used for paper when a paperclip is nowhere to be found.

The two metal sheets are placed, slightly overlapping, in a punch press which, in one operation cuts a pair of parallel incisions in the double thickness. The metal between the slits is bent down to form a permanent fastening "button" under the surface of the bottom sheet.

A single such fastening is said to be the equal of three rivets in strength. Savings of up to 25% of the labor time needed for conventional fastening processes is claimed.

Called the "Williams Metalacing" process, it has been patented by Crockatt Engineering Co.



Longest Steel Forging **Part of a column for a 50,000-ton die forging press, this steel forging made by Bethlehem Steel Co. is 110 ft long and weighs 145 tons. Here it is being given a final straightening.**

Size Problems Raised By Heavy Presses

But Industry Just Sets Records

It takes bigger steel forgings to make presses to make bigger aluminum forgings.

From the standpoint of engineering materials, the Air Force's "heavy press" program is impressive not only because of the large fabricated structures it will make possible, but also because of the immensity of the components of the presses themselves. From both angles, new developments have been coming thick and fast.

Recently, U. S. Steel's Homestead District Works poured an ingot weighing 250 tons. When this ingot has been forged and machined down to a little less than 100 tons, it will form a finished tie-rod 64 ft long and 42 in. thick for a 20,000-ton extrusion press. Poured from two open-hearths, it was one of the biggest ingots ever made.

About the same time, Bethlehem Steel Co. released some details on what it called "the world's longest steel forging." When finished it was 110 ft long, 16 in. thick, and weighed 145 tons. Along with two similar sections, it will form one of the six columns for a 50,000-ton die forging press.

Unlike the steel people, the aluminum industry still talks in "pounds." But aluminum ingots also are getting bigger as "heavy

(Continued on page 11)

What They Said . . . .

MAGNESIUM "Certainly the automotive body of tomorrow will be considerably lighter. In the U. S. and in England it seems to be assumed that plastic will solve the weight-reduction problem. We find that the answer is not plastic, but magnesium."—R. J. Cross, Managing Director, Essex Aero, Ltd., England.

PLASTICS "We now have plenty of concrete evidence to offer in support of our belief that the plastics industry has become a mature, reliable and essential part of our industrial life. . . .The day is definitely gone when properly fabricated plastics can be dismissed as a substitute material, or as unreliable in performance."—Frank E. Selz, General American Transportation Corp., Feb. 16, 1953.

ZIRCONIUM "In 1953, it is anticipated that quantity fabrication of zirconium on a full commercial scale will be achieved."—Dr. R. B. Gordon and W. J. Hurford, Westinghouse Atomic Power Div., Mar. 24, 1953.

continued from page 8

presses" draw near, and the problems associated with size are growing, too. Among them is the problem of bringing large aluminum billets up to forging or extrusion temperature in a reasonable length of time. The answer seems to be induction heating.

The Aluminum Co. of America has announced that it is now using a low-frequency induction heater to heat a 7700-lb ingot to 750 F in 50 min. The same job in a furnace or soaking pit would take 12 hr. Similar induction heaters for ingots have been put on the market previously by such firms as Magnethermic, Inc. The latest firm in the field is Loftus Engineering Corp., which recently announced that it had heated a 30-in.-dia aluminum billet weighing 4300 lb to 760 F in just 31 min.

Battelle Announces New Materials

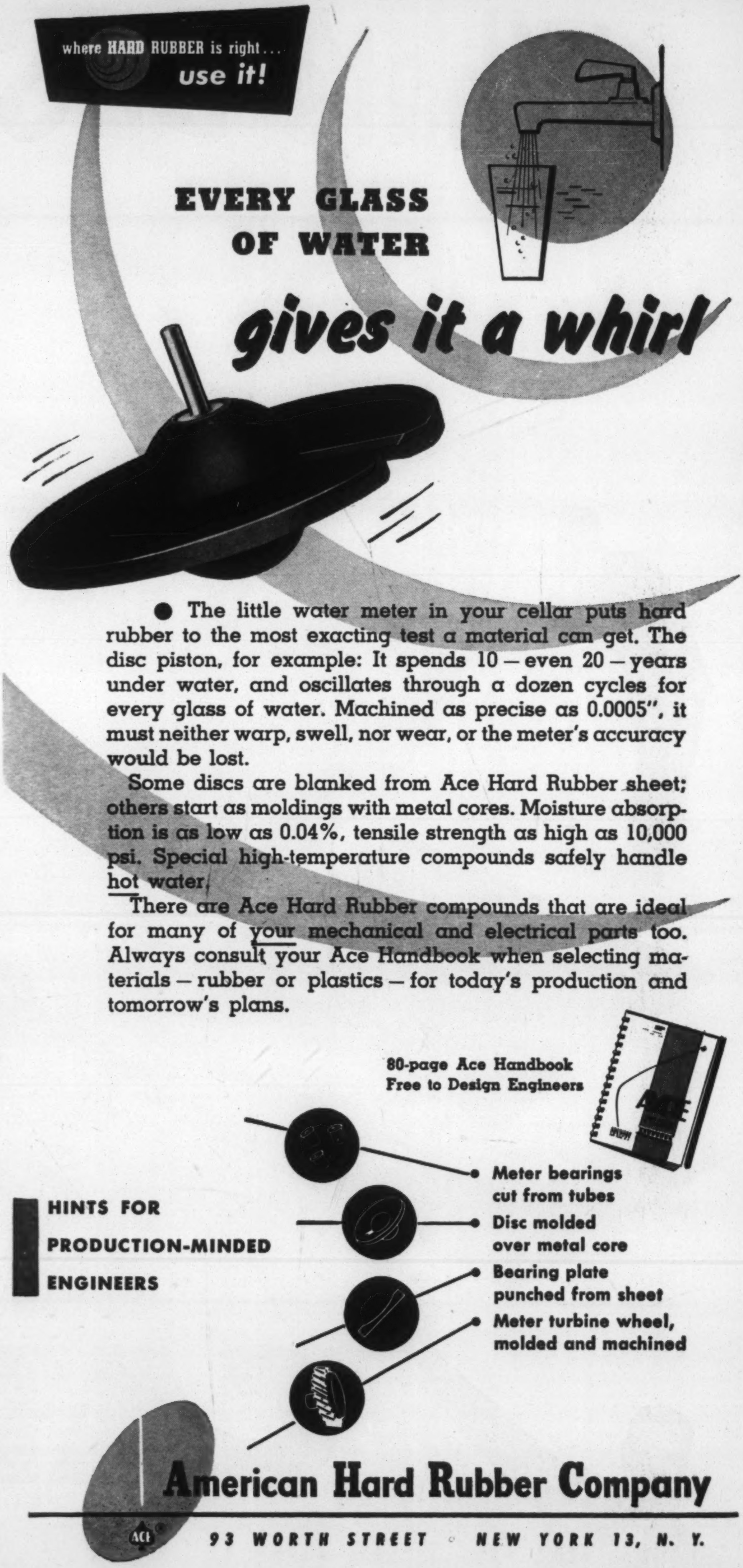
Two new materials have been developed recently at Battelle Memorial Institute. One is a copper-base alloy for springs and the other is an aluminum-antimony compound which may compete with germanium and silicon for use in transistors.

The copper-base alloy was developed as a possible replacement, in some uses, for the scarce and expensive beryllium-copper alloys. It contains about 10 nickel, 1.5 silicon and 4% aluminum.

Conductivity and Strength

Good electrical conductivity, corrosion resistance and springiness have been built into the new alloy, although the conductivity and strength are not quite as high as in copper-beryllium alloys. Like those alloys, the new material can be formed soft before hardening. Tailor-made for electrical contact springs in large accounting and billing machines, the alloy may also be suitable for aircraft instruments and electrical equipment where high-strength springs are needed.

(Continued on page 202)



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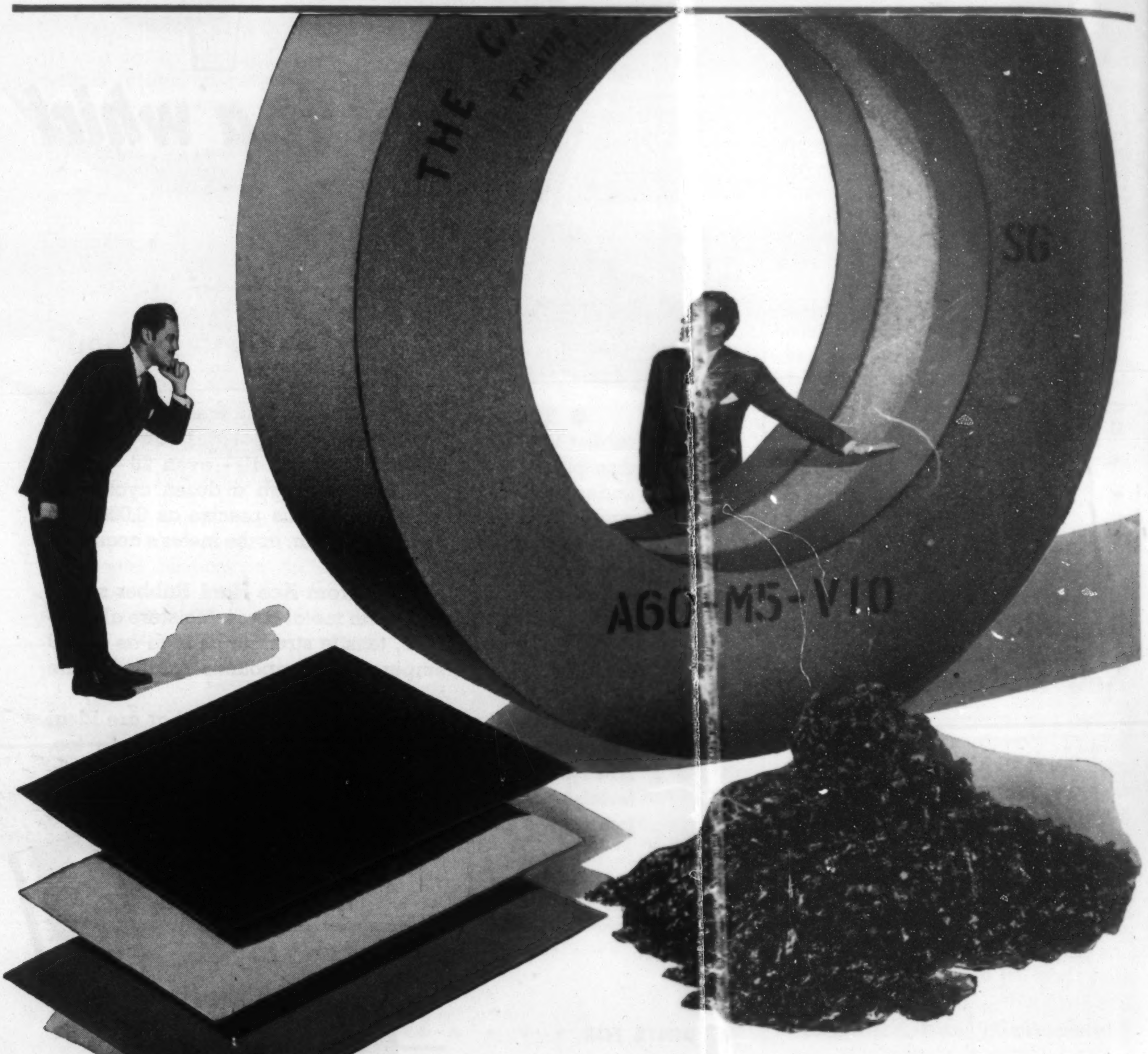
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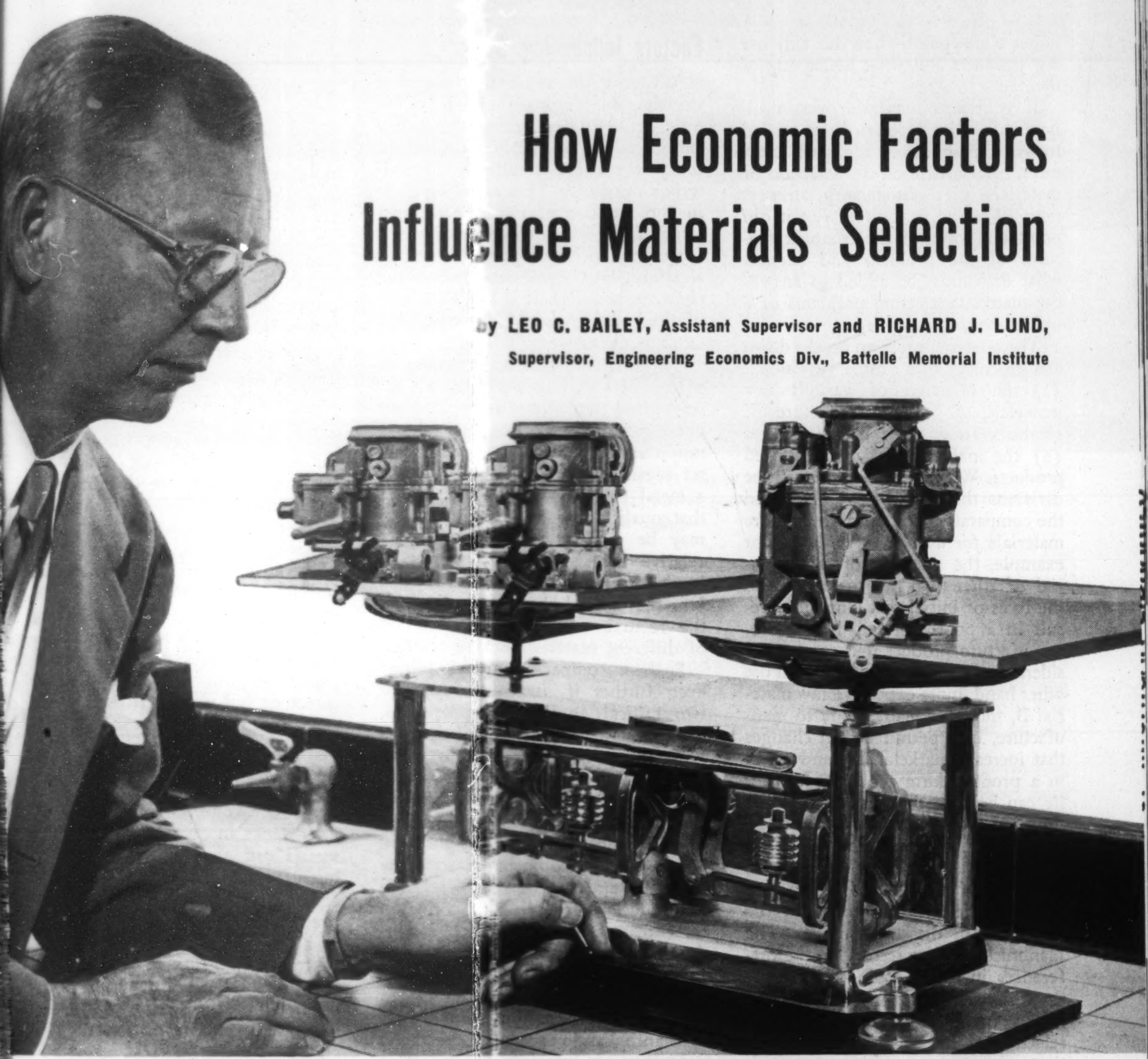
How Economic Factors Influence Materials Selection

by LEO C. BAILEY, Assistant Supervisor and RICHARD J. LUND, Supervisor, Engineering Economics Div., Battelle Memorial Institute



Price and supply picture must be considered when choosing engineering materials. A trend in automotive field is to adopt designs that are suited to use of two or more materials to meet changing conditions. Here shown are two aluminum (left) and a zinc (right) carburetor of same design.

There are few simple rules for selecting engineering materials. The problem is a complex one. Here the authors explain (1) the factors that must be considered, and (2) the data that should be studied before the final choice is made.

THE SUCCESS OF A manufacturing venture depends largely on how much it can give to its customers in the form of superior products while keeping the cost of making and marketing these products at a minimum. One important aspect of manufacturing superior products at a minimum cost is the problem of making a sound, economic choice of engineering materials.

Unfortunately, the road to such a choice is rough. There is a natural human tendency to look for easy answers and for generalized rules of selecting the best materials for manufactured products. The widespread application of rules of this type may be attributed to both the constantly increasing number of materials available and the short time allotted to product design and production planning. Other frequent sources of error in selecting the best material for the product arise because we still know far too little about the customer's viewpoint—how he will use our products and what he expects of them.

If generalizations and oversimplification of the problem have misled many companies in the past, how can a brief article on the selection of materials give satisfactory answers now? Frankly, it cannot. But it can point out some of the complex features of the problem and suggest what data must be added to answer the materials-selection problems of a manufacturing company.

The selection problem breaks down conveniently into three divisions: (1) the selection of various raw materials, (2) the manufacture of products from these materials, and (3) the marketing of manufactured products. Within each of these three divisions there may be accumulated the comparative costs of two or more materials *for an equivalent use*. For example, the selection of raw material A rather than raw material B on the basis of initial cost alone may result in a poorly designed, costly-to-manufacture product that meets considerable consumer resistance. On the other hand, more expensive raw material B, though equally costly to manufacture, may permit design changes that increase marketability and result in a profit-making product. It readily can be seen that this example of the "mine-to-market" cycle can be varied in many ways, and the selection of a material must be made on the basis of costs in all three divisions of the problem to avoid the possibility of disastrous results. The manufacturer who recognizes the differences in materials in each of the three divisions of the problem, and allows for these differences in the selection of his materials, has a distinct advantage over his competitors who do not.

The selection problem is further complicated by the economic factors of supply and demand that affect *each division*. To fully and accurately foretell the effects of such factors on a particular material poses a time-consuming task. The amount of detailed study that is worth while varies for individual companies, depending on the number of product units that are produced and the relative expense of alternative materials that may be involved. Frequently, a simple comparison will highlight the gross differences in the plus and minus values of alternative materials so that further refinements may not be necessary.

Factors Influencing Selection

Whereas up until the last few decades the engineer could choose only between steel, iron, and a few simple alloys of nonferrous metals, today there are hundreds of materials available. This rapid increase in the number of engineering materials from which to choose has led frequently to better products and to a stimulating competition for the consumer's dollar. If it has also complicated the matter of choice, the sacrifice seems worth while.

The first wholesale screening takes place when all possible materials are segregated according to their engineering properties. For example, if minimum requirements have been set regarding the tensile strength of a metal part, the number of metals that qualify may be small. Then it may be necessary only to compare relative costs of several metals in ingot form, costs of processing them into the desired shape and size, and the relative acceptance or rejection of different materials by the market.

Such a comparison is simplified even further if, instead of one or two critical engineering properties, the "mesh" of the screen includes a half dozen characteristics in some particular combination that is uncommon. It is this constantly increasing awareness and understanding of engineering behavior that has led to the development of so many materials and to the careful design of products before risking money on their manufacture. Strength, lightness, corrosion resistance, suitability for use on high-volume production equipment, hardness in relation to maintaining precise dimensions, heat resistance, and even such esthetic properties as color and luster have become influential.

A critical phase in the selection of engineering materials is the study of how they affect the attitude of consumers toward the product. The influence of the consumer on choice of appropriate engineering materials is often hard to measure. Obviously, expensive materials add to the ultimate cost of a product. It is apparent also that extra costs or cost saving in processing different materials in these years of expensive labor and equipment are frequently much greater than any initial difference in the price of the materials. But, the customer is the final judge of what constitutes a fair price for the product. He makes his decision from an intimate knowledge of how he intends to use what he buys, how much he values some real or imagined difference in manufactured goods offered to him, and a seemingly endless list of similar factors. Price is only one of many buying motives, and the amounts spent everywhere on various forms of advertising seem to indicate that there are a large number of manufacturers who do not think price is the most important motive influencing purchase of their products.

The factors listed above are a necessarily incomplete summary of reasons why an estimate must be made of the relative value of different materials to the market, including the differences in product design and performance that are determined by these materials. Because many of the factors are difficult to evaluate in dollars and cents, qualitative differences in materials can be ranked or judged only roughly, which complicates the problem of sound selection.

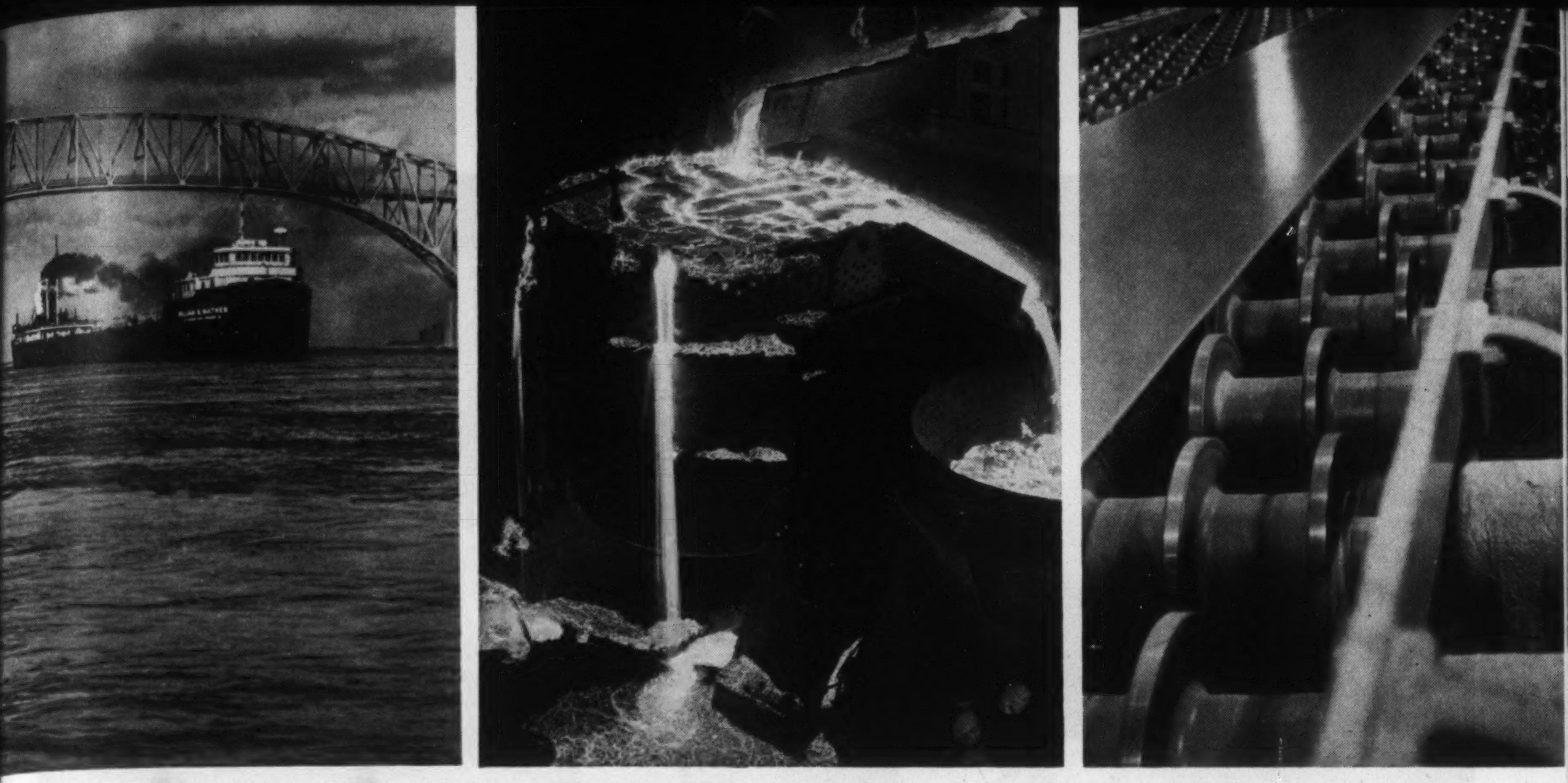
Another group of factors influencing materials selection include government controls, stockpiling, and direct or indirect restrictions on imports and exports. These seldom affect the prices of materials as seriously as they do the availability of critical materials. Especially in wartime, such controls are of overriding importance in determining what materials can and cannot be used in manufactured products. Because government controls are frequently unpredictable, this factor may be used as a criterion for the final screening of most promising materials. Then, if available, the best material may be used. If not, the second or third best material becomes a necessary interim choice.

Initial Costs of Materials

The first and most obvious element in the cost of a material is its price delivered to the plant where it will be used. Minerals which are the source of most of the materials used in manufacturing differ markedly in the economics of their occurrence or production. The differences affect both short- and long-term price movements, availability, and reliability of supply.

The major factors that influence the economics of minerals are (1) isolated occurrence, (2) unpredictable discovery, (3) limited supply, (4) increasing use of metal scrap.

Isolated Occurrence—It is unfor-



INITIAL COSTS of materials are the total of a number of separate costs including: (1) cost of mining and transporting the raw material (left); (2) cost of producing the material from the mineral or the ore (center); (3) cost of producing the semi-finished shapes suitable for use by the manufacturing plant (right).

tunate but true that ores, mineral-bearing material from which a metal can be extracted economically, are very restricted in geographic occurrence. Even the most widespread commercially important mineral deposits are minute areas on the earth's surface. Moreover, the very nature of mineral concentration in the earth's crust is such that most mines are in areas where mountains, arid climate, or removed soil cover makes large-scale habitation or industrial concentration virtually impossible. And to this must be added the fact that the remoteness of the deposits makes transportation and the relative degree of advance in transportation technology an important factor in the economic feasibility of developing ore deposits.

Since the term "ore" implies the possibility of economic extraction, it is somewhat doubtful that it should be applied to any mineral deposit, however rich, until that deposit can be reached with necessary equipment and men for exploitation. Having explored just about all of the surface outcrops of ore deposits in the United States, Western Europe, and the fringes of Africa and South America, it remains for us to either go farther underground in areas already explored or to penetrate into the interior of the more unpopulated and forbidding areas of the world. This may be a costly undertaking, and surely the future supplies of metal will reflect the increasing difficulty of discovering, mining and transporting ores.

The isolated occurrence of metallic ores has another important significance. As we deplete commercial deposits of minerals in our own country, two courses remain. One is to do research and development work on deposits of lower and lower grades so that, through technology, we can use these less desirable materials economically. The second is to spend perhaps equal amounts of money abroad or to stimulate its expenditure by foreign investors so that high-grade foreign deposits will be available to meet the needs of industry in the United States. This, in turn, implies that we are willing to depend on foreign sources of ore, that we will spend or invest money abroad, and that there is some hope that the costs of bringing in ore from outside will be lower in the long run than those of extracting metal from low-grade deposits in the United States.

Limited Supply—The limited supply of mineral resources in any country is the second important fact of mineral economics. Even the most backward countries in the world today are probably using their mineral resources faster than they are being formed by geologic processes—therefore, there is a net world loss each year. At any one moment we can never be sure of the amount of any particular mineral in the world or in a single country, and certainly can never be sure of the demand and supply factors that will make it economic to exploit a deposit of any particular concentration.

This situation regarding reserves arises for several reasons. First, since deposits are so scattered, and since we know nothing about any but discovered deposits, there is no way for accurately predicting the ultimate reserves. Second, even proved or measured reserves are subject to wide margins of error. It simply is not economic to do the drilling and surveying necessary to determine the exact extent and richness of a deposit until there is some production-prompted reason for doing so. This is particularly true for many of the ores of nonferrous metals which occur in nature as veins of varying size, shape and concentration. Because deposits of petroleum and coal are found in sedimentary rocks characterized by broad and more or less tabular shape, there are many more data on the probable extent of proven and ultimate reserves. But even these estimates of reserves are based upon our past experience and the extent of rock strata similar to those that have been productive in the past. Further, the estimates frequently make but little allowance for changes in the technology of mineral extraction.

One thing seems certain. Given a

Marketability of end product is an important factor in choosing materials. In this case, plastic proved particularly attractive and adaptable to the design.

static economic and technologic situation, the amount of a mineral that can be extracted from the earth is finite. But if anything can be done to change the economics or technology of the situation, a different quantity may be obtainable. Therefore, there is a continuous battle between depletion and technology in the mineral industries. As extraction becomes more difficult, industrial users will be forced to pay higher prices or to switch to some other material.

This immediately raises the question of whether we can continue to depend on technology to offset depletion so that there is virtually no end to our domestic mineral resources. Unfortunately, the answer is not simple. For years we may offset an upward trend in prices due to depletion, but each new complication introduced into mineral processing adds to the problems and costs of mining. Ultimately, these will take their toll. Furthermore, mining history shows that other deposits are discovered at unpredictable intervals in other parts of the country or of the world that also can take advantage of technological developments in mineral processing and transportation. If there is any semblance of free trade, these new deposits may be exploited at lower costs and deliver metal at lower prices, so that, for all purposes of practical economics, the older deposits are eventually considered exhausted.

It has been mentioned previously that no engineering material is completely without competition from some other material. If these are not minerals but are produced from "flow" resources, there is little problem of exhaustion. Plastics can be produced alternatively from depletable mineral resources or from agricultural and forest products. Many ceramics can be produced from nonmetallic minerals so abundant that no shortage can be foreseen during even the next few centuries.

Metal Scrap—The accumulation of metal scrap is an important consideration of mineral economics. Although many industrial products consume metals in ways so they cannot be recovered, many others permit recovery and reprocessing at costs which compete with those of primary metals. Technology has played a role of increasing importance in recent years by shifting the demand for relatively scarce metals in irrecoverable uses to more abundant metals, nonmetals and organic materials. Examples of this include the increased use of glass food containers and the development of organic resins for protective coatings that formerly depended on metallic compounds of copper, tin, lead or zinc. Moreover, increased industrialization and better transportation has made it relatively easy to collect segregated scrap that can be reprocessed into products that would formerly have required primary metals.

The part played by scrap recovery in extending our supplies should not be underestimated. For example, about 35% of the lead, 7% of the zinc, 27% of the copper, 7% of the aluminum, and 25% of the steel that is consumed in the United States in recent years has been recovered from scrap. The recovery rates for some of the noble metals are much higher.

Supply Economics of Nonmetallic Materials—Before leaving the subject of what factors influence the price and price fluctuations of engineering materials, it may be well to mention some of the factors peculiar to nonmetallic materials versus the metals. Ceramics as a group, ignoring for the moment an increasing number of special-purpose materials that contain minerals as scarce and scattered as many metal ores, are generally made from minerals of great relative abundance compared to the metals. Researchers are studying their physical and chemical properties to an unprecedented extent and are begining to understand fundamental properties that promise an even greater future.

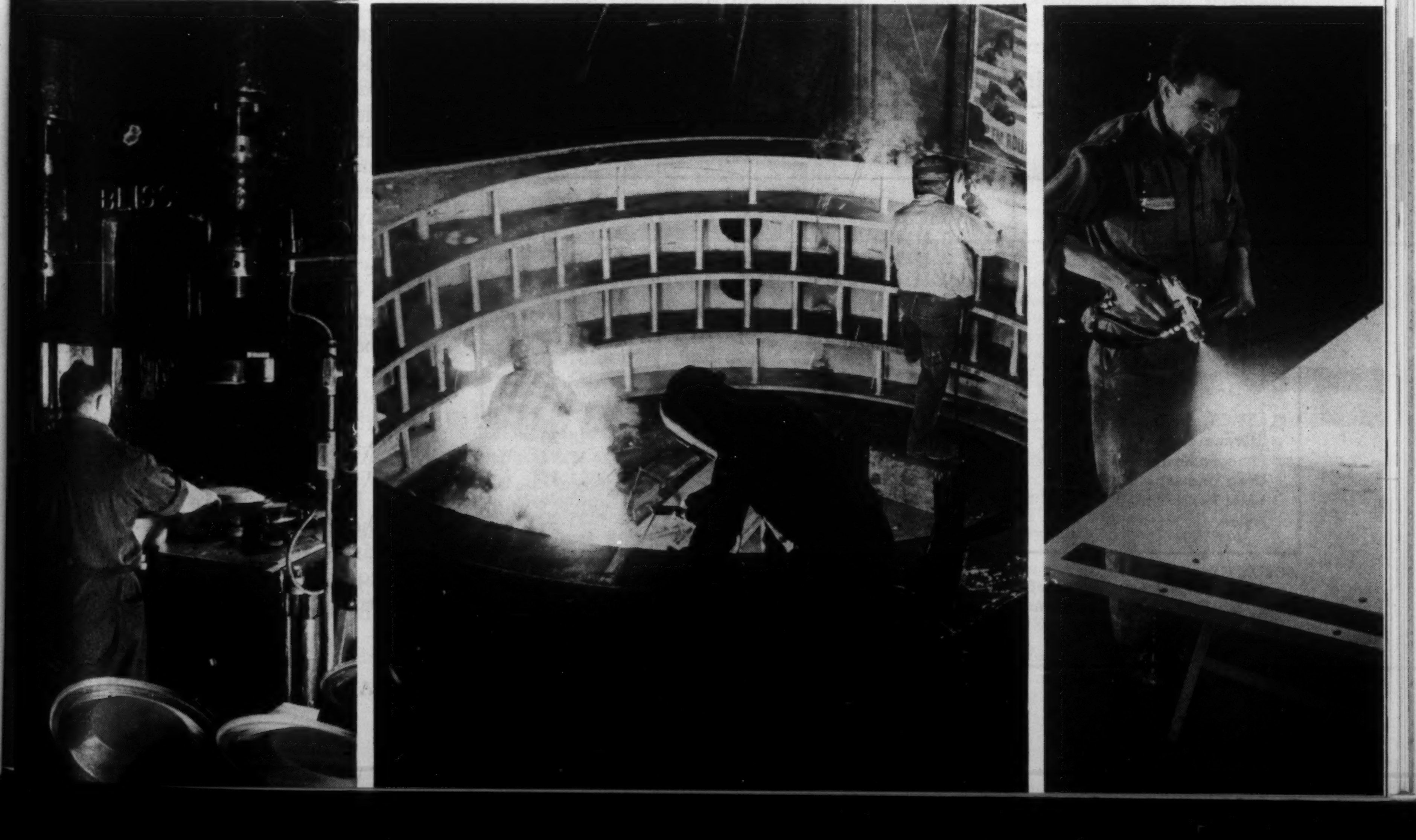
The plastics are highly variable engineering materials, and it is unfortunate that so large a segment of the general public has lumped them as one class. In many respects, the vinyls, cellulose plastics, styrenes, polyethylene, acrylics, melamines, phenolics and urea plastics are as different as a similar listing of major metals. To their fundamental differences should be added all of the many properties that can be modified by compounding, lamination or reinforcement, filling and processing.

Plastics are made of relatively low-cost materials in very expensive plants by semiskilled laborers. Since their production is not burdened by some of the mining uncertainty that characterizes metals, the prices of plastics are more stable and may be expected to drop as productive capacity increases. Furthermore, most of the plastics can be made by several processes and from several different materials. Many of those that are made from the products of natural gas or petroleum now could be made from coal or even agricultural raw materials if there were economic justification for a change. As with any new materials, there have been many mistakes in designing and manufacturing plastics and in the selection of material for particular applications. Misapplications have annoyed the public and have lost money and good will for producers. But the number of these mistakes is declining as both the producers of plastic raw materials and those who fabricate them have learned to match fundamental properties with ultimate uses, remedying shortcomings with appropriate design, fillers, reinforcing materials and plasticizers.

Production Costs

Given a particular raw material at a certain price, a manufacturing company is still faced with many problems before it can put a saleable product on the market. Progress in metallurgy, welding, metal processing, design, coating if protection is needed, and the relative economics of performing all production operations on alternative materials, largely determine the marketability of a product both pricewise and performancewise.

Certainly one of the factors contributing to the "popularity" of plain-carbon steel, and one which strongly influences the price of products made from it, is the huge amount of technical information and accumulated experience on processing this basic material into products for consumer and industrial markets. A similar influence has played an important part in the expansion of aluminum production and consumption during and since World War II. Thousands of workers in hundreds of plants developed the skills and knowledge necessary to form and join aluminum during the war, when it was a military necessity to do so. Once the desirable properties and working characteristics of the material became widely known, it was a relatively simple step to find civilian uses for aluminum products, to put aluminum processing machinery to peacetime work, and to make products that were attractive to the market and competitive with other



PRODUCTION COSTS *involved in fabricating materials into a finished product may include: (1) cost of forming or shaping (left); (2) cost of joining (center); (3) cost of finishing (right).*

Relative Costs of Materials in Primary Form

Ordinarily, production and market factors will limit an engineer to a few materials from which he must choose on the basis of the price and availability of the materials in primary form. But the prices of most engineering materials are usually reported in tons, pounds, or some other unit of weight which conceals the fact that what really must be determined for fair comparison between materials is cost per equivalent weight. For example, nylon at $1.60 per lb is actually cheaper than bronze at $0.34, because the density of nylon is only about one-eighth that of metal. Even price divided by density can be very misleading, because it may not be possible from a design standpoint to substitute one material for another on a volume for volume basis. Actually, what is needed is at least a rough design of the part in question as it might be made from each material under consideration. Then the price for the amount of one material needed to do a particular job may be compared with a fair degree of accuracy with the price of others in similarly appropriate forms and quantities. This is the concept of cost in equivalent use.

For a complete comparison, the following table is suggested:

	A	B	C	D	E
Price of primary materials in equivalent quantities					
Cost of processing to desired form and quality					
Cost of assembling and/or joining					
Estimate of the value of market intangibles:					
Lightness					
Appearance					
Corrosion resistance					
Ease of maintenance					
Totals					

As a point of reference for beginning a comparison process of this type, the accompanying table shows recent prices of a representative selection of engineering materials. The prices per pound and per cubic foot are given to emphasize the differences that arise when equal *volumes* of two or more materials may be interchanged in design of a manufactured product.

metals.

Ordinarily, there is a vicious cycle in the development and widespread application of a new material. Small-scale production keeps prices high. High prices, coupled with insufficient user and public consumer knowledge of the material, discourage choice of the material for mass-produced and mass-marketed products. This lack of large-scale demand, in turn, discourages increased production of the basic material. Only the largest or most optimistic companies try to buck this cycle. Large consumers wait for quantity production and low prices; potentially large producers wait for substantial demands. If neither group will take the necessary plunge, the material may be neglected for years.

What sort of influences eventually break these deadlocks? War-time production has done so for a few materials such as aluminum, magnesium and titanium. Trends in consumer acceptance constitute another important influence. For example, increasing consumer interest in lightness, corrosion resistance, ease of maintenance and high-temperature resistance in metal products influences manufacturers to consider new alloys, new metals and new nonmetallic materials.

But one of the most inopportune types of influence is that brought about by technical and popular ballyhoo about a material before it is adequately known to support economic utilization on a large scale. This sort of thing may come about, for instance, when a new method of extracting a metal from its ore results in very low prices relative to established metals, or when a metallurgist discovers some new alloy that has wonderful characteristics despite its real scarcity, or when a production process is developed that promises to boost output of a material, the ores of which are in acutely short supply. Generalizing, it is the sort of thing that can develop when one specialist, carried away by his own findings, forecasts a future for a material that is not justified by the unsolved problems at some other stage between mine and product. Popular writers, seeing this sort of technical forecast, blow up the bubble until everyone is talking about the great new material. Actually, if the whole picture were presented, the bottlenecks would be quite evident, but many small manufacturers and a few large ones may lose their shirts through misinformation.

What are some of the production differences that affect the ultimate costliness of a material? One material may be more costly because it is more difficult to machine. Another may be difficult to hot form or cold form without special processing. Another may require investment in equipment which is either more expensive initially or more costly in operation. Another may be easy to put into the desired shape but may have physical properties such that components made of the material cannot be joined or assembled by an economical method. A few materials such as magnesium and titanium may require special safety precautions or special processing atmospheres.

Price per Unit Volume of Major Metals and Plastics

Material	Average 1950 Price per Lb	Weight, Lb per Cu Ft	Average 1950 Price per Cu Ft
METALS (a)			
Steel	$0.0386	490	$ 18.91
Copper	0.2154	558	120.19
Lead	0.1329	708	94.09
Zinc	0.1451	446	64.71
Aluminum	0.1770	168	29.74
Magnesium	0.2202	109	24.00
Titanium	5.0000	281	1,405.00
Silver	12.5000	655	8,187.50
Tin	0.9553	359	342.95
PLASTICS			
Styrene Resins (b)	0.2800	65	18.20
Phenolic Resins	0.2300	78	17.94
Urea and Malamine Resins	0.2300	92	21.16
Vinyl Resins	0.4200	84	35.28
Nylon	1.6000	72	115.20

SOURCES:

(a) "Iron Age," Jan. 1, 1953 and Lessing, L. P., "The New Age of Metals", "Fortune," Jan. 1953.

(b) U. S. Tariff Commission, Synthetic Organic Chemicals—U. S. Production and Sales.

Others may be difficult to plate or coat with protective material — or they may require special design care to prevent fatigue. But all of these characteristics are tied up with the basic physical and chemical nature of the material plus what is known about processing the material at the moment. These same factors apply to nonmetallic engineering materials.

The examples of economic differences in materials due to production advantages or disadvantages are too numerous to even outline. But let's review a few samples. Aluminum can be extruded on relatively inexpensive presses in a variety of shapes and thicknesses. If properly designed, the extrusions can eliminate many costly steps in the manufacture of metal products. In addition, the dies for extrusion work are cheap and may be interchanged quickly on an extrusion press. Similarly, metals that can be welded or die cast by simple techniques are generally cheaper to use than those that must be bolted, riveted or machined. Copper and aluminum have been difficult to weld, because of their high thermal conductivities. Only recently have methods been developed for large-scale welding of aluminum pipe and tubing. Titanium has proved difficult to process by any method that requires melting or extreme heating of the metal. Even steel, the workhorse metal, is subject to major processing changes. The entire field of steel extrusion is still in its infancy, but the much-publicized Mullins Kold-Flo process serves as a good example of progress in cold impact extrusion.

In the less extreme, these same production-cost differences exist for almost all engineering materials at each stage in their fabrication and assembly. Even a choice between two grades of plain-carbon steel must often be made on the basis of differences in processing costs or difficulties. This type of situation has been exaggerated by the tendency of some companies to isolate research and development from production and design. It may also be somewhat prevalent in a large company because of "over-specialization" in the design staff. One man, for example, who writes specifications for springs as a part of his design work, may select a spring material that will far outlast the product in which it is used. That is, a specialist is quite apt to think of his specialty as all-important and to select the best materials within this restricted field without considering the economics and performance requirements of the product into which the part will be incorporated.

Somewhat related to production economics is the high cost of inventory. A company making a large number of products or even a few products with many parts and a high rate of obsolescence will lose money if it allows special materials to be specified, purchased and accumulated without very good reason. It is frequently more economical to buy a limited number of multipurpose materials, even though they may cost a few cents more per pound initially than the special-purpose alternate, and to keep inventory as low as possible.

Taken as a whole, the costs of production equipment and labor have risen out of all proportion to the initial cost of raw materials. This fact, coupled with the increasing complexity of manufactured products, means that most of the ultimate cost of many products represents processing costs, rather than the cost of raw materials. If the trend continues, as expected, it will become increasingly important to establish production cost differentials for all possible materials. Once established these factors may nullify the apparent advantages of many materials that are cheap in their unprocessed condition but expensive to form, fabricate or maintain.

Market Factors

In essence, the demand for engineering materials of particular physical and chemical characteristics is what an economist would call a derived demand. That is, materials are bought only to make products that will meet performance standards set by the customer, whether industrial or private. Few of these customers care whether the product is made of one metal or another—or of any particular material. What they do care about is that it will perform as desired. It is also necessary to consider some intangibles such as good appearance based on color and shape. These esthetic factors, while not so important for industrial goods as for consumer products, are of increasing importance as the standards of living and levels of education rise in the United States.

Are there any noticeable trends in market factors that a manufacturer can use as an aid in selecting engineering materials? Probably yes. There does seem to be an unmistakable trend towards lightweight products as the population ages, as a means of saving on materials handling and transportation expense, and as more women are employed. Furthermore, lightness of equipment and materials has been demonstrated to reduce fatigue among workers and to permit greater output. And, as labor becomes more and more expensive, the trend to light materials as a source of production savings may be expected to increase.

Another important market trend is that towards materials of greater corrosion resistance or materials which can be protectively coated at a low cost. There is an increasing awareness of the waste, often irrecoverable, due to corrosion. This awareness is prompted by the many articles on conservation and extension of the useful life of equipment and by high maintenance costs. It may be expected to continue, prompting manufacturers to specify corrosion resistant materials or those which can be economically plated or coated.

Another reflection of the increasing cost of maintenance is the trend towards the "do it yourself" type of product. While this is particularly noticeable in the manufacture and sale of consumer products such as paints, hardware, tools, lumber, and other building materials, it is probable that many industrial customers are also shying away from the high cost of repairs. This trend towards easy maintenance runs counter to trends towards automation and complexity. How strong it may be outside of the manufacture of home repair products is not known, but it may ultimately influence the design and hence the materials of many manufactured products.

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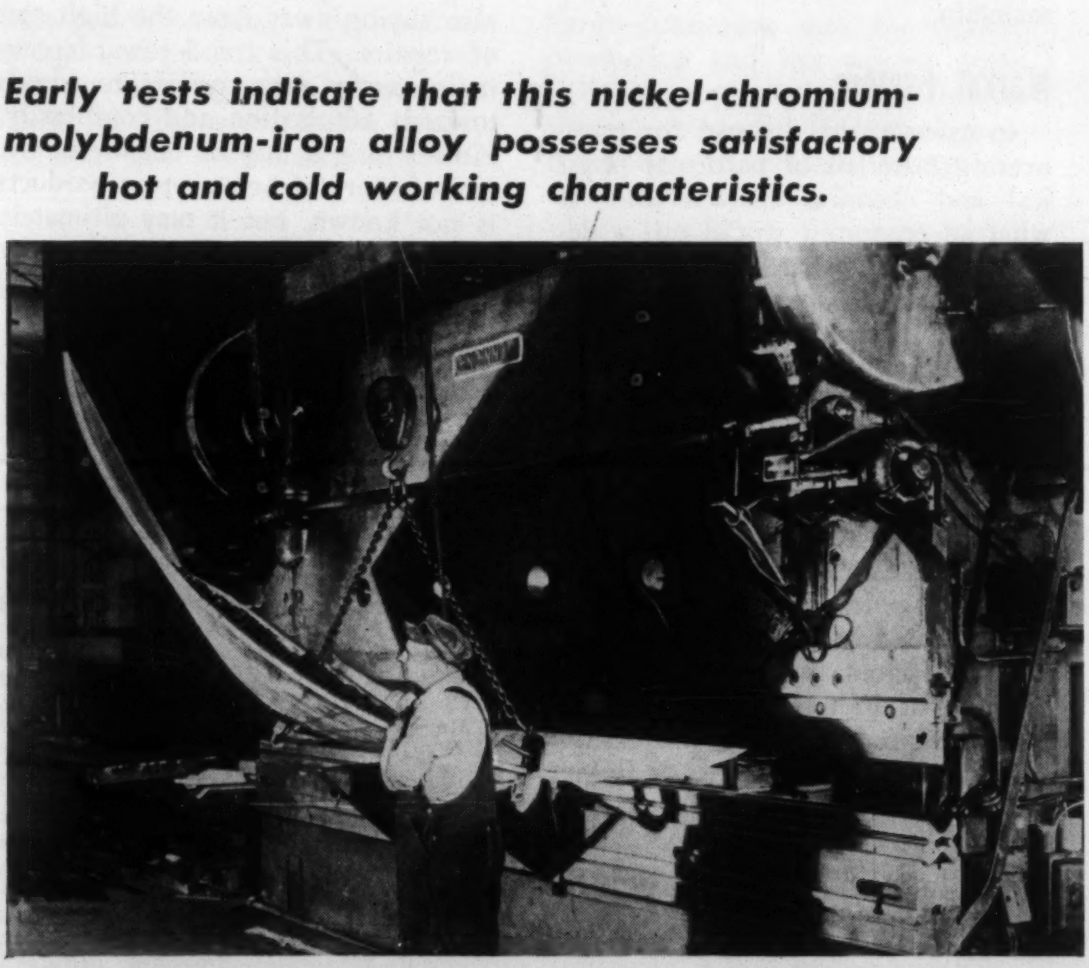
PICTURE CREDITS: Chrysler Corp., Westinghouse Electric Corp., U. S. Steel Corp., General Electric Co., Steel Founders' Society, Plaskon Div.

Sulfite pulp digester lined with Hastelloy Alloy F being assembled for erection at the mill site.

A New Corrosion Resistant Alloy —Its Properties and Possible Uses

—A NEW MATERIALS PREVIEW

Early tests indicate that this nickel-chromium-molybdenum-iron alloy possesses satisfactory hot and cold working characteristics.



Cold-pressing the top head segments of a digester to hemispherical form.

● HASTELLOY ALLOY F, a new corrosion resistant alloy, has been announced by the Haynes Stellite Co. This new nickel-chromium-molybdenum-iron alloy resists attack by oxidizing and reducing acids, can be used in handling both acid and alkaline solutions, and resists pitting and stress corrosion cracking in chlorine solutions. It has good hot-working characteristics and is sufficiently ductile for intricate cold-forming applications.

Hastelloy F is stronger and about as ductile as the austenitic stainless steels. Its electrical resistivity is somewhat higher than 18:8 and its thermal expansion is about 10% lower. The density of Alloy F is similar to that of comparable nickel-base alloys. It is nonmagnetic and its modulus of elasticity lies in the normal steel range. Hastelloy F also has good high temperature properties.

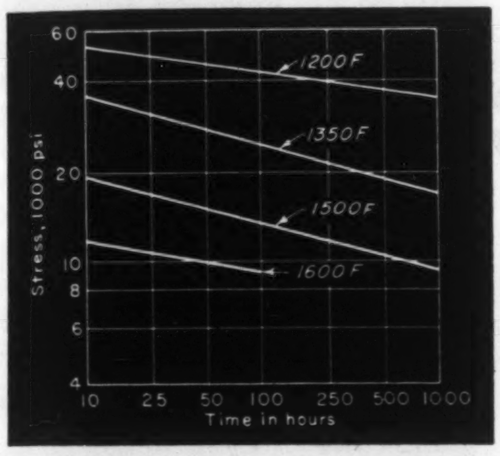
Corrosion Resistance

Hastelloy F has excellent resistance

to boiling 10% sulfuric acid, but is not recommended for use in boiling sulfuric in concentrations greater than 20%. The alloy has good resistance to air-free sulfuric in concentrations up to 30% at temperatures to 175 F. It is attacked by boiling 65% nitric acid. Boiling 70% phosphoric acid can be handled successfully, but boiling 85% acid attacks the alloy rapidly.

Hastelloy F has good resistance to sea-water attack although it apparently is susceptible to under-gasket corrosion, and equipment should be designed to minimize crevices and contact areas which can form regions of low oxygen concentration.

Stress-corrosion tests in boiling 42% magnesium chloride solutions on samples of Hastelloy F under stresses equal to the yield strength showed no cracking after 500-hr exposure. This solution is used frequently to determine the susceptibility of 18:8 to stress corrosion. The new alloy also has good resistance to pitting in a solution of 5% ferric chloride-10% sodium chloride, a solution which tends to pit chromium-bearing alloys.



Stress-rupture properties of sheet solution annealed at 2125 F and air cooled.

Fabricating

Hastelloy F can be welded by the metallic arc, inert-gas-shielded arc and resistance welding methods. Pressure vessels to be used in the process industries have been lined by the resistance welding procedure known as Smithlining. The welded linings have successfully passed hot-forming, hot-bending, thermal shock, fatigue and other tests designed to indicate the quality of the composite material. Plate of Hastelloy F bonded to carbon steel by Smithlining has been cold-pressed into hemispheres, brake formed and cold-dished.

Effect of Welding and Heat-Treatment—14-Gage Sheet

Condition of Metal	Tens. Str., Psi	Yld Strength (Dividers) Psi	% Elong in 2 In.	Bend, Deg	Hardness (Rockwell D)
Solution Annealed—Not Welded	108,500	29,700	45.5	180	86
As-Welded	104,900	41,300	35.5	180	98 (weld)
Welded-Heated 2 Hr at 1000 F*	108,100	39,100	30.5	180	85 (weld)
Welded-Heated 2 Hr at 1200 F*	109,500	54,600	34.0	180	—
Welded-Heated 2 Hr at 1400 F*	110,000	54,300	32.5	105	—
Welded-Heated 2 Hr at 1600 F"	113,000	48,200	28.5	75	—
Welded-Heated 2 Hr at 1800 F*	108,900	50,600	26.5	65	—
Welded-Heated 2 Hr at 2000 F*	102,100[1]	45,600	21.5	180	—

* *Furnace-cooled.*

[1] *Fracture occurred in weld metal.*

Mechanical Properties

	Sheet (0.065 In.)	Bar Stock (1-In. Dia)
Yield Strength, 0.2% Offset Psi	50,900	48–53,000
Tensile Strength, Psi	106,000	108–116,000
Elongation in 2 In., %	52	40–46
Reduction of Area, %	—	47–54
Izod Impact, Ft-Lb*	—	58–100
Rockwell B Hardness	84	89–93
Brinell Hardness	—	160–180
Bend Angle, 2t	180°	—

NOTES:

Material solution annealed at 2125 F.

* *Notched specimens at room temperature. Additional tests conducted at −58 F showed no loss of toughness.*

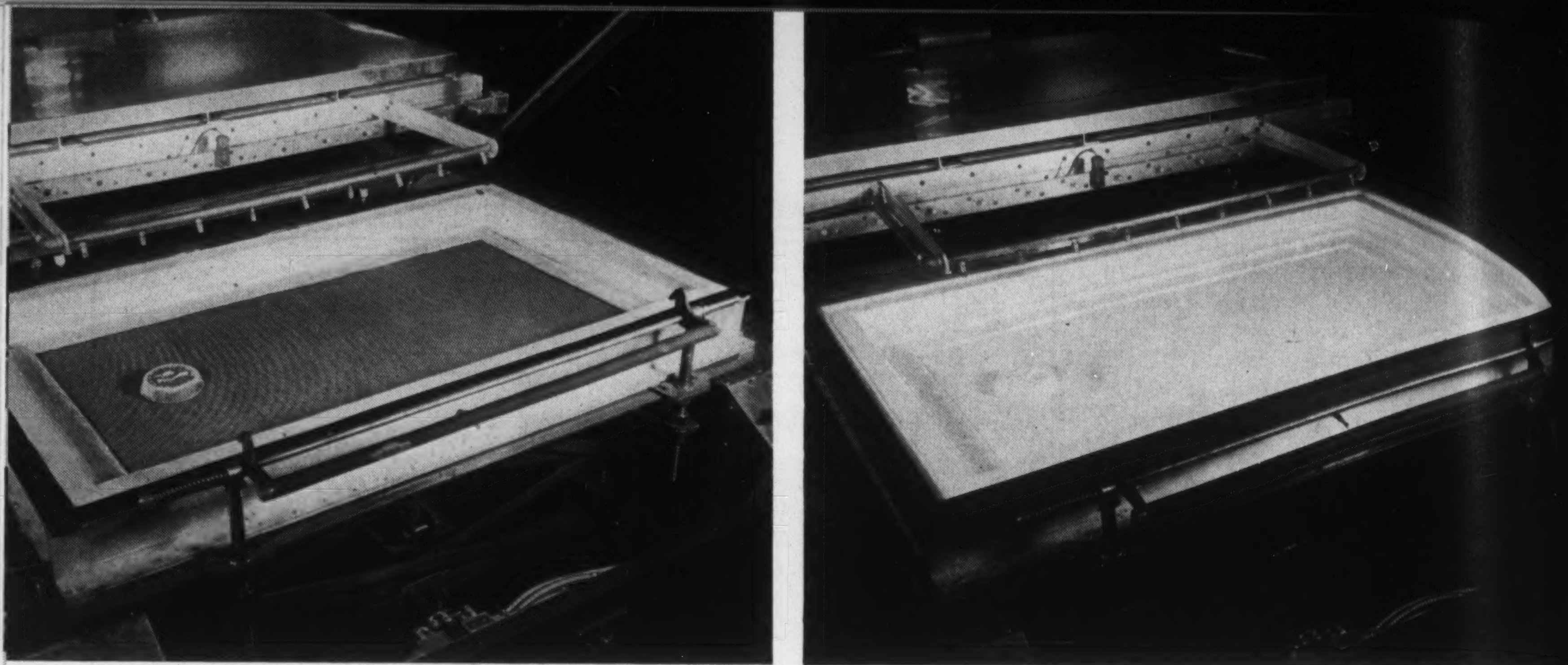
Applications

Hastelloy F has shown excellent resistance to corrosion in the top vapor zone of a sulfite digester. It has also been suggested for equipment designed to handle the new duplex pulping processes which require acid cooking followed by alkaline cooking. The alloy appears to be especially attractive for service in the vapor phase region where corrosion of other alloys has been high.

Although the alloy has not been fully tested, it appears to offer possibilities for service in the chemical, petroleum and other process industries.

Composition and Physical Properties of Hastelloy F

NOMINAL COMPOSITION, %:	
Nickel	45.5
Chromium	22
Molybdenum	6.5
Columbium+Tantalum	2
Tantalum	0.5 minimum
Carbon	0.8 maximum
Manganese	1.5
Tungsten	1.0 maximum
Cobalt	2.5 maximum
Iron	Balance
PHYSICAL PROPERTIES:	
Density Lb/Cu In.	0.295
Coeff. of Exp per F (68-1800 F)	10.2×10^{-6}
Elect Res Microhm-Cm	112
Magnetic Permeability	<1.2 at 116 oersteds
Modulus of Elasticity, Psi	29×10^{6}



Vacuum forming is particularly suited for thin parts of large area. Left: mold in place ready for loading. Right: finished formed sheet.

Vacuum Formed Thermoplastics for Large, Thin Parts

by **KENNETH ROSE,** **Mid-Western Editor, Materials & Methods**

New rigid polystyrene sheet stock makes possible broader application of this technique. Cellulosics and some vinyls can also be vacuum formed.

● A TECHNIQUE THAT IS receiving increased attention for forming thermoplastic parts of large area and thin sections is vacuum molding. This method makes use of heated sheet stock which is formed by exhausting the air from under the sealed sheet and letting atmospheric pressure press the plastics sheet into the mold.

Some of the significant features of vacuum molding are:

1. It makes possible the forming of large, thin pieces that could not be molded in closed molds.
2. Mold costs are greatly reduced.
3. Equipment in general is simple and requires no large capital investment.
4. Surface finish at the present time is not as lustrous as in other molded pieces.

Materials

Materials that can be formed by vacuum methods include the cellulosics, polystyrene, and some of the vinyls. The list could probably be lengthened if need arose for this type of formed part in other materials. Polystyrene, because of its combination of good properties and low cost, is especially favored for vacuum molding.

A broader application of this technique is made possible by the development of new rigid thermoplastic sheet stock. The material, known as Styron 475 sheet, is polystyrene modified for high impact strength by the addition of a small percentage of butadiene. It is available in sizes as large as 40 by 72 in. These large sheets are of uniform thickness; they are held to tolerances of less than 0.002 in. The sheets are well suited to production of large area parts at high speed with low cost equipment.

Pieces fabricated from this sheet stock show good dimensional stability and very little internal strain, two factors which are of prime importance in determining the suitability and service life of the parts. In addition, the material has excellent electrical properties, toughness, low water absorption and high impact strength.

How It Is Done

Typical of the vacuum forming technique is that performed on a demonstration machine at the Dow

Chemical Co. laboratories. The machine consists of a vacuum box with a stiffened wire mesh bottom and a clamping frame to fit around the top of the box. A vacuum pump is connected to the machine so as to exhaust air from the box through the mesh bottom. A heating frame rides on tracks horizontally above the top of the box, about 5 in. above the clamping frame. This heating frame can be moved forward to cover the top of the box during the heating cycle, or backward out of the way during the placing of the sheet or removal of the formed piece.

Low-cost molds work very well with vacuum forming, and the possibility of important savings in tool costs is one of its most significant advantages. The mold itself is under no stress greater than atmospheric pressure, so the forms can be made of wood, plaster, soft metal, etc., all easily worked at minimum cost. The machine itself is simple in design, with no highly stressed parts, close-tolerance units, or high-cost materials.

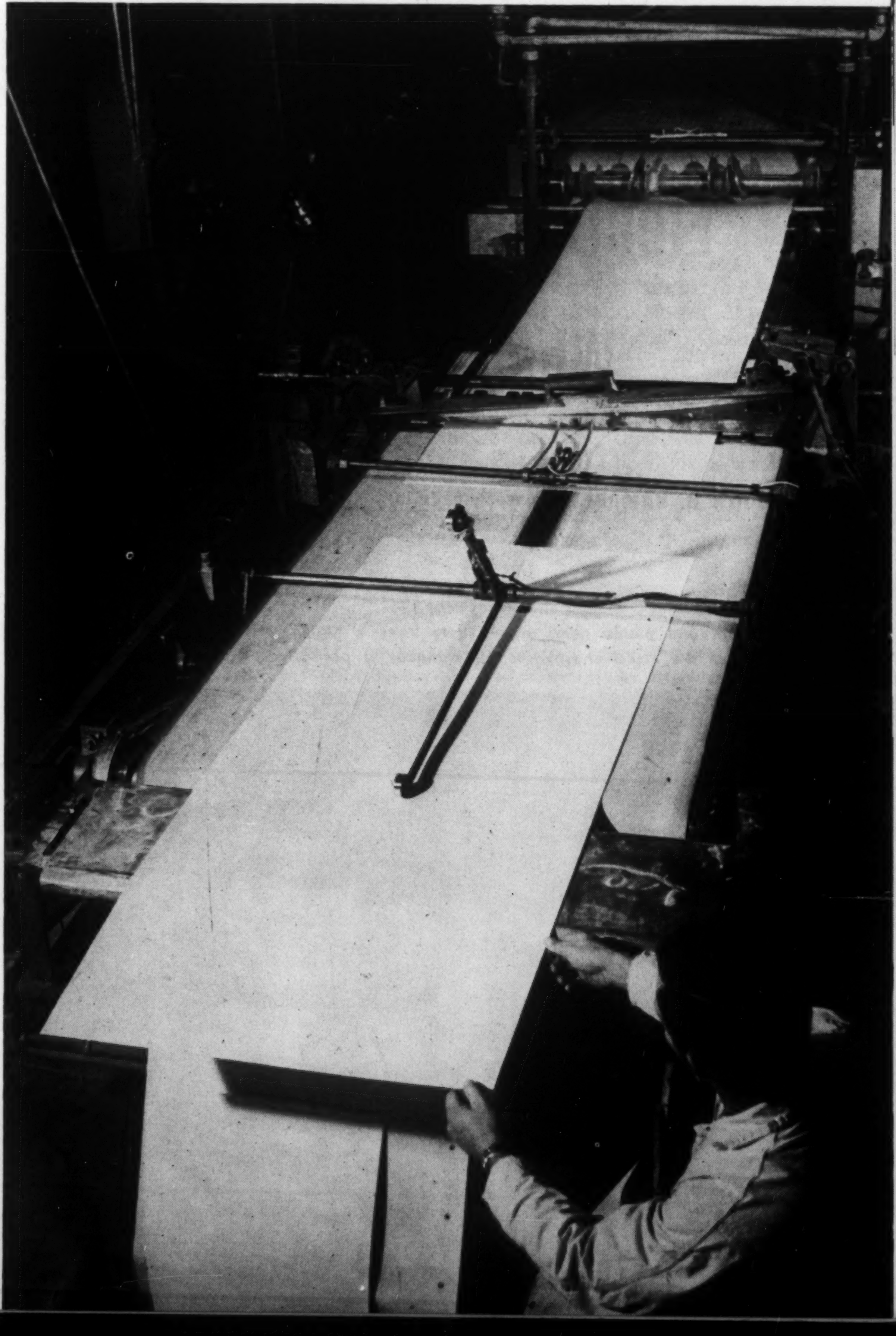
To begin the forming, the mold is placed in the vacuum box and a sheet of the plastics material is placed over the top of the box. The clamping frame is fitted over the edge of the sheet and fastened, sealing the top of the box. The heating frame is then moved forward over the sheet and a few inches above it, and current is applied to the electrical heating coils in the frame. The heater temperature is held at about 600 to 700 F. Higher temperatures would tend to cause local overheating, while lower temperatures would require too long to bring the sheet to softening heat. At this temperature range the sheet will come to 300 to 330 F within about 40 to 50 sec. As the sheet starts to warm it wrinkles, but when uniformly heated it is stretched smoothly across the top of the box.

The air inside the box is now exhausted so that atmospheric pressure may force the heated plastics sheet down over the mold. The sheet is forced down tightly around the mold. Heat is maintained for a few seconds, then the current is cut off and the heating frame is slid back. The formed sheet is ready for removal as soon as the vacuum is broken and the clamping frame removed. A trimming operation to remove surplus stock around the molded portion of the sheet usually completes the processing of the piece.

Vacuum forming permits a degree of flexibility in its operations. The forming machine is made in a range of sizes, and the sheet, if too large for a single mold, can be formed over several molds of the same kind or over miscellaneous molds for which the sheet thickness is suitable. Thickness of material usually ranges from about 0.040 in. to 0.080 in. The heating frame can be electrically heated by means of resistance coils, or it can use a panel of conductive glass. The energy input is about 15 watts per sq in. of plastics surface. Other heat sources can also be used.

An interesting possibility in connection with vacuum forming is the use of inserts. Inserts of many kinds can be easily placed during the forming of the hot sheet stock. A refrigerator shelf, for example, was required to be formed with a metal reinforcing strip in the top edge to stiffen the piece and to prevent tearing. A simple arrangement in which the ends of the strip were inserted in saw kerfs in blocks of wood for positioning gave satisfactory results. For another piece, blocks of wood were wrapped in the sheet stock to give a desired bulk at a given location in the piece. Such blocks can be embedded to provide anchorage for wood screws or similar fastenings, also.

New polystyrene sheet is modified for high impact strength. Uniform thickness assures good dimensional stability.

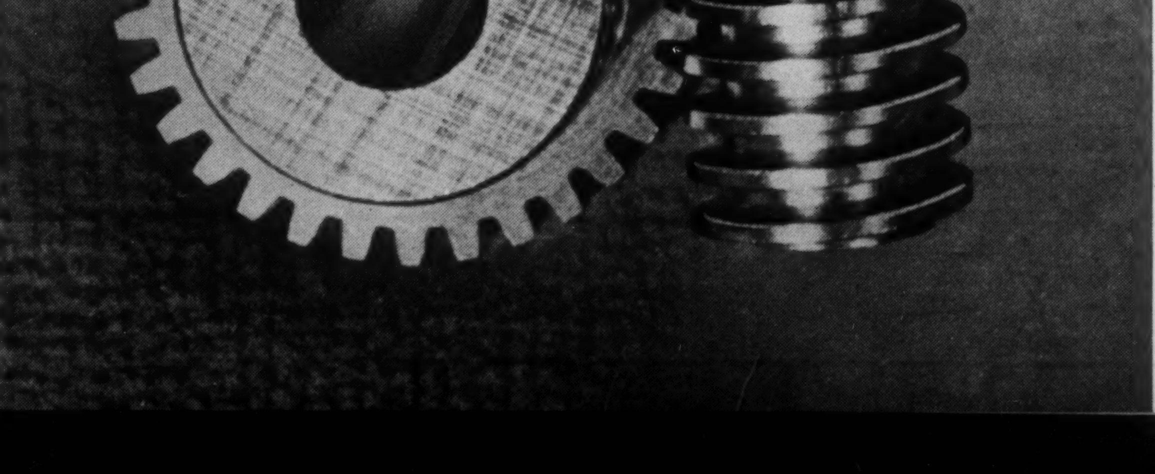


NICKEL COATING applied by electroless process to the grooves of this aluminum piston saves one overhaul on an engine produced by Wright Aeronautical Div. of Curtiss-Wright.

Electroless Nickel Plating: Where It Stands Today

by JOHN B. CAMPBELL, Associate Editor, Materials & Methods

STEEL worm and pinion gears shown here have a highly uniform 1-mil nickel coating. Hardness of the nickel-phosphorus alloy makes it particularly adaptable to gear teeth.



Recent advances in chemical plating indicate that method is commercially feasible . . . . Makes possible corrosion resistant nickel plates on surfaces inaccessible to electroplating . . . . Also offers certain advantages over conventional plating.

● ALMOST SEVEN YEARS AGO, two investigators in the National Bureau of Standards published details of an entirely new nickel plating process. Because it made use of an ordinary chemical reaction rather than electrolytic action, they called it "electroless" nickel plating.

Despite the saving in electrical equipment, the new process was costly, and it seemed unlikely that the method would soon find any wide commercial application. However, the process is being used today in several important commercial applications and its possibilities for the future are being widely investigated.

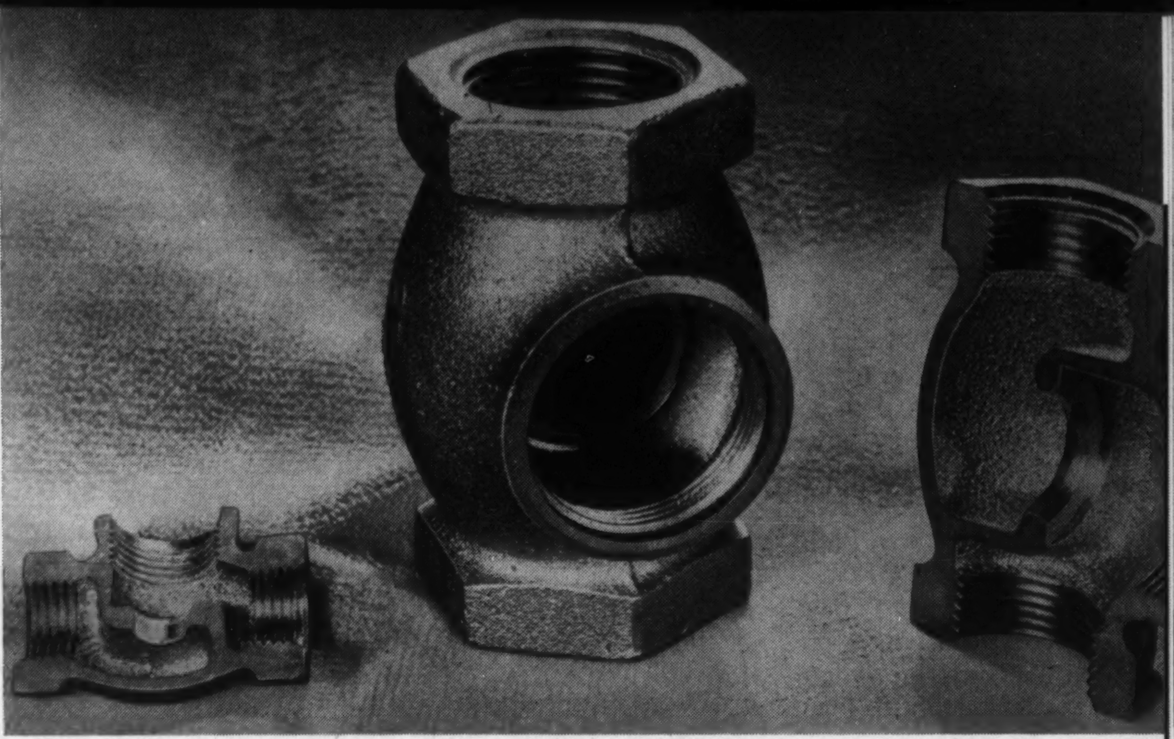
Just recently, renewed interest has been aroused by the announcement of a modification known as the "Kanigen" process by General American Transportation Corp. Although little specific data on the new process is available, the information that has been released appears to indicate that significant improvements in the direction of greater practicality have been achieved.

This article is an attempt to summarize the information currently available on "electroless" nickel plating and to indicate the present and probable future status of the process.

Advantages and Limitations

The chief advantages of the "electroless" nickel plate, as compared to electroplated nickel, can be summarized as follows:

1. It is applicable to many parts which cannot be successfully electroplated.
2. For a given thickness, it appears to offer better corrosion protection to the base metal.
3. Considerably less nickel is required to insure a given minimum plate thickness.
4. It is more wear resistant.
5. Hardness can be increased by



BRASS globe valve bodies, cross-sectioned to show interior plate (1 mil). Although brass is not naturally catalytic to the chemical reaction involved, a simple technique makes it adaptable to electroless plating.

a short heat treatment.

The chief limitation is its much greater brittleness as plated. The cost picture varies widely, with the older processes considerably more expensive than electroplating and the "Kanigen" process appearing to offer actual economies in many cases.

Properties of Plate

Actually, the so-called nickel plate is a nickel phosphorus alloy composed of 90 to 95% nickel. It is known that considerable phosphides are present. Much has yet to be learned, however, concerning the physical metallurgy of the plate.

Adhesion—Good adhesion can be obtained on steel, aluminum, copper and brass, nickel, cobalt, gold, silver and palladium. Good plates cannot be obtained on tin, cadmium and zinc. Although lead is generally considered unsatisfactory some investigators have not given up hope of extending the process to that metal. Obtaining good adhesion on aluminum is somewhat more difficult than on other metals.

Compared to electroplate, adhesion in the older chemical processes is not quite as good, but adhesion of the "Kanigen" plate is said to equal or exceed that of electroplate. Developers of the "Kanigen" process say that a plated steel specimen pulled to failure in a tensile machine shows no chipping or flaking of the plate. Although it is reasonable to presume that the bond strength differs according to the base metal involved, no comparative data is yet available. It should be noted that, because of the greater hardness of the "electroless" plate, the stresses set up in it by such action are greater than those in an electroplate.

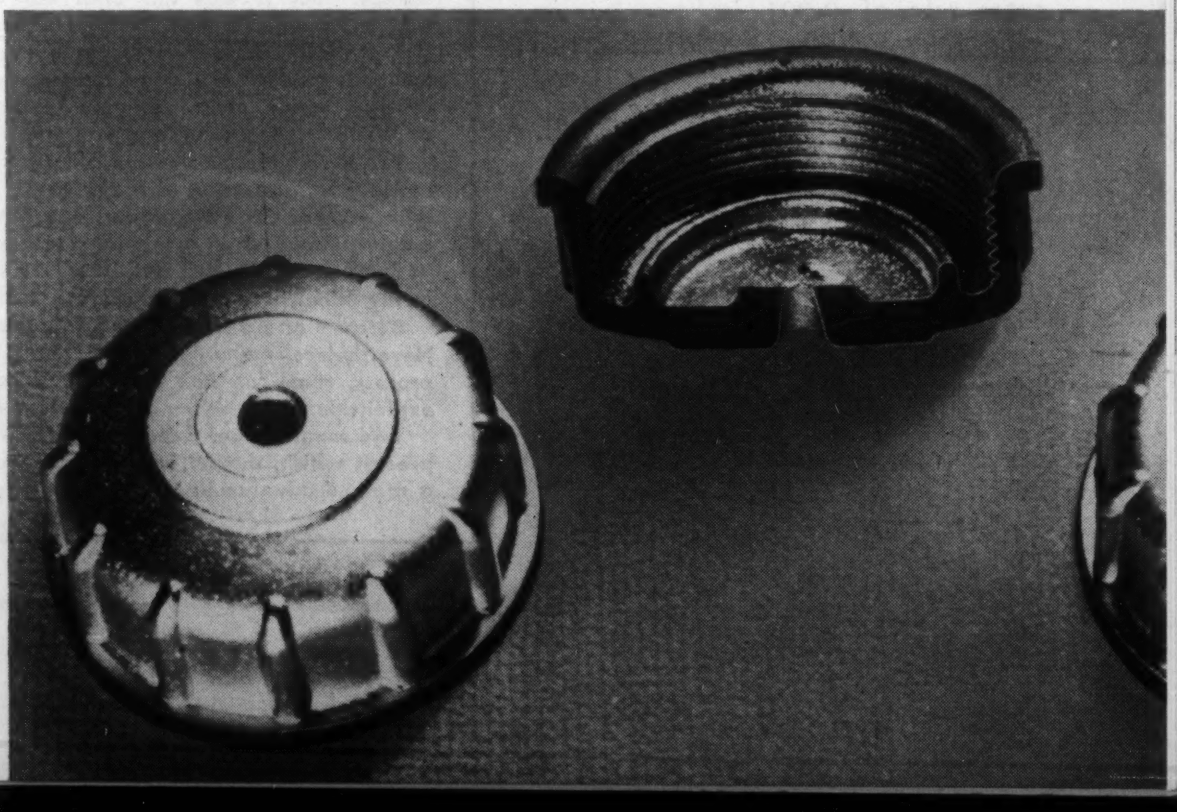
Uniformity—Variations of thickness of the plate can easily be held within 10% of the average thickness. This means that the plater, having determined that one mil was the minimum desirable plate thickness on a given part, could operate his bath to produce a plate averaging 0.0011 in. Such uniformity is independent of the shape of the part and extends to sharp angles, undercuts and interior surfaces. A comparable tolerance in electroplate might run anywhere from 0.0013 to 0.0030 in., depending upon the complexity of the part.

Corrosion Resistance and Porosity—The "electroless" nickel-phosphorus plate itself seems to have corrosion resistance "almost equal to that of wrought nickel," according to the Kanigen Div. But effectiveness in preventing corrosion of the base metal depends to a great degree upon its porosity. The porosity of "electroless" nickel plate is said to be decreased by heat treatment, but even without heat treatment it is reported to be less than in electroplated nickel of the same thickness. The Kanigen Div. says 2-hr. immersion in hot aerated water shows up *no pores at all* in its plate, even at thicknesses less than ½ mil.

If, as is claimed, nickel plate produced by the "electroless" process is actually less porous than electroplate, it should be expected to perform better than electroplate in routine salt spray and humidity cabinet tests.

Results of such tests which have been published so far have been presented in rather generalized terms. However, the "Kanigen" developers claim that their plate shows up two or three times better in salt spray tests than nickel electroplate of equal thickness from less than ½ mil on up. They also say that "Kanigen" plates have successfully withstood salt spray exposure for periods of time of the order of two weeks. Salt spray tests conducted on ½-mil "Lustralloy" produced in an "electroless" process being promoted by Metal Processing Co. showed only a slight superiority for it as compared to electroplate and that was after the "Lustralloy" had been given a standard half-hour heat treatment at 750 F. In humidity cabinet tests, however, the heat treated "Lustralloy"

PHENOLIC parts can also be plated, though special surface preparations are necessary. Application to thermoplastics is limited because of the relatively high temperature of the plating bath.



showed marked superiority to electroplate. In a 20-day test in which ½-mil electroplates failed after three days, heat-treated "Lustralloy" of the same thickness failed in one case after 16 days and in the other case not at all. The marked difference in performance between salt spray and humidity cabinet tests carried over into results obtained on "Lustralloy" and electroplates which had been heated 25 hr at 800 F. In this case, all samples failed from salt spray in 9 to 12 days, but in the humidity cabinet, electroplate failed after six days and "Lustralloy" not at all in 20 days.

Hardness and Strength—The coating produced by the "electroless" process is considerably harder than an electroplated nickel coating and can be increased in hardness by proper heat treatment. Plated from the standard "Kanigen" bath, the hardness of the coating ranges from 550 to 650 Vickers, averaging 600. "Lustralloy" ranges from 400 to 500 Vickers, averaging 450. The Kanigen Div. says it can vary the hardness from 400 to 900 Vickers, the implication being that not all of this variation must be accomplished by heat treatment.

The coating of 600 Vickers hardness deposited by the Kanigen process is quite brittle—too brittle to be subjected to flexing in service or fabrication. The 450 Vickers hardness coating is probably less brittle, but nevertheless is easily frangible.

Only a small amount of data is available on wear resistance. A test of "Lustralloy" was conducted by rotating a ½-in. drill rod hardened to Rockwell C-60 at 400 rpm with 100-lb load on the test panel for 20 hr. The one-mil coating wore through in 9 hr, for an average wear rate of 0.00011 in. per hr. A similar test on low alloy steel showed a wear rate of 0.001 in. per hr, or nine times as high. On "Nicarb", the wear rate was 0.00015 in. per hr, or roughly 25% more than on "Lustralloy". Hardness of the "Lustralloy" used in this test was checked at 64 Rockwell C.

According to several investigators, heat treatments at temperatures up to 1100 F increase not only the hardness but also the ductility of the plate. Hence, toughness, which is not a property of the as-plated nickel, can be added by heat treatment.

Appearance—As in electroplating, the appearance of electroless plates depends largely upon the surface finish of the base metal. With proper control, bright plates can be obtained.

Heat Treatment

A hard, brittle material as plated, the nickel-phosphorus layer increases in hardness after a short heat treatment at temperatures up to 1100 F. Even more interesting is the finding of some investigators that ductility also increases as a result of heat treatment. A more or less standard heat treatment of a half hour at about 750 F has consequently been developed. Heat treatments above 1100 F reportedly lower room-temperature hardness in some cases.

There is no general agreement on the reasons for such behavior. Some believe that the increased hardness is due to precipitation-hardening and the greater ductility is a result of stress relief. Others are inclined to dispute the precipitation hardening theory. Up to this time the metallurgy of the nickel-phosphorus plate has not been investigated sufficiently to provide a final answer.

Most current applications for "electroless" nickel plate make no use of the heat treatment mentioned here. However, some of the advantages of the heat treatment are being obtained indirectly, inasmuch as some parts are being stress relieved at temperatures up to 1800 F after plating. In such cases any softening of the plate is not considered a drawback, and its value in corrosion protection may be enhanced as a result of the local melting and flowing in of the plate during heat treatment.

Applications

In general, it is clear that for corrosion protection applications the potential field of "electroless" nickel plate is essentially that in which nickel electroplate is presently used —or would be used, if not prevented by strictly process considerations. In the face of an unfavorable economic comparison, this broad potential must be considerably narrowed for most chemical processes now in use. Until the older "electroless" processes can be made less expensive, it is likely that their commercial applications will be confined to those where:

1. The part is so large as to make electroplating impractical, such as extremely large components.
2. The metal surface is completely beyond the throwing power of an electroplating bath, such as the interior of small tubes.
3. The part is irregular, and uniformity of coating is important enough to override economic considerations, such as screw threads and gears.
4. Nickel conservation is sufficiently important to over-ride economic considerations.

If, as seems increasingly likely, experience shows that the new nickel plate is significantly more effective in protecting the base metal against

Background of "Electroless" Nickel Plating

The chemical reaction which is the basis of "electroless" nickel plating was encountered accidentally by Abner Brenner and Grace Riddell of the National Bureau of Standards in 1946.

The reduction of a nickel salt in heated solution by hypophosphites had appeared in the literature as early as 1845 and had been studied in detail over a 20-year period from 1911 to 1931. It was known that this reaction was catalyzed by several metals. But it was not until the team of Brenner and Riddell went to work that any practical results were achieved.

Essentially, what they did was to control the composition and temperature of the solution so that the spontaneous reduction was inhibited and only the catalytic reaction would occur. They could then plate out nickel on any metal which acted as a catalyst without filling up the bath with "black" nickel.

For certain metals which did not act catalytically, they worked out techniques which made them adaptable to the process. In some cases this involved merely brief contact with a more electronegative metal while immersed in the bath; in others it required a brief immersion in a solution containing a catalytic metal such as palladium.

Brenner and Riddell published the results of their work in the form of two papers in the NBS "Journal of Research," dated July 1946 and November 1947.

Because of economic factors, the process appeared to have only limited practicality. Nevertheless, many large and small companies began to "tinker" quietly with the process, some for their own internal application and others with a view to possible exploitation. A number of installations were set up for actual production plating.

Two months ago, General American Transportation Corp. announced its "Kanigen" process which, though based on the work of Brenner and Riddell, appears to represent a marked advance in practicality.

corrosion, there are two further possibilities: (1) "electroless" nickel plate may be considered for use in corrosive environments more severe than ever entrusted to electroplated nickel; and (2) the ability to use coatings of much less minimum thickness for a given job of corrosion protection may remove the economic barrier in some applications.

Another important factor: the "electroless" nickel plate also offers good wear resistance, markedly superior to electroplate. Moreover, this property can be varied over a wide range, partly by modifications of plating technique, but mostly by heat treatment. It is believed that no current applications of "electroless" nickel plate have been designed to take full advantage of its wear resistant qualities, but the possibilities in a field such as instrument gearing are obvious.

An "electroless" process which is actually *cheaper* than electroplating obviously not only offers all of the possibilities outlined above, but, because of its inherent technical advantages, threatens to make serious inroads on the nickel electroplating field. It might well capture large fields of application, such as automotive hardware. Such a process is "Kanigen", says its developers. Although it will take a couple years to determine the real effect of the "Kanigen" process, widespread interest has already been shown by industry.

Current applications of "electroless" nickel plating are limited both in scope and in the amount of information available on most of them. The principal field of application now is jet engine parts, though an important projected field is the interior of tank cars, an application which spurred the development of the "Kanigen" process.

About jet engine parts, little can be said at this time. But as a lining for tank cars carrying corrosive chemicals, the new "Kanigen" nickel plate is expected by its developers, the General American Transportation Corp., to be cheaper than and to outlast the baked-on enamel previously used.

Plates on Nonmetallics

According to the Kanigen Div., its process can be used to provide a nickel plate on plastics and other nonmetallics. Bonds which, though not as strong as on metals are nevertheless satisfactory, are claimed.

The principal limitations to plates on plastics are the following:

1. Softening of most common thermoplastics at the temperature employed in the plating bath.
2. Possibility of organic contamination of the bath.
3. Necessity for a preliminary sensitizing of the surface, since it is not naturally catalytic to the chemical reaction.

Even where the first two limitations do not hold, the third would necessarily make the process somewhat more expensive for plastics than for metals.

A foreign lamp manufacturer is understood to be making successful use of "electroless" nickel plates on both glass and phenolics.

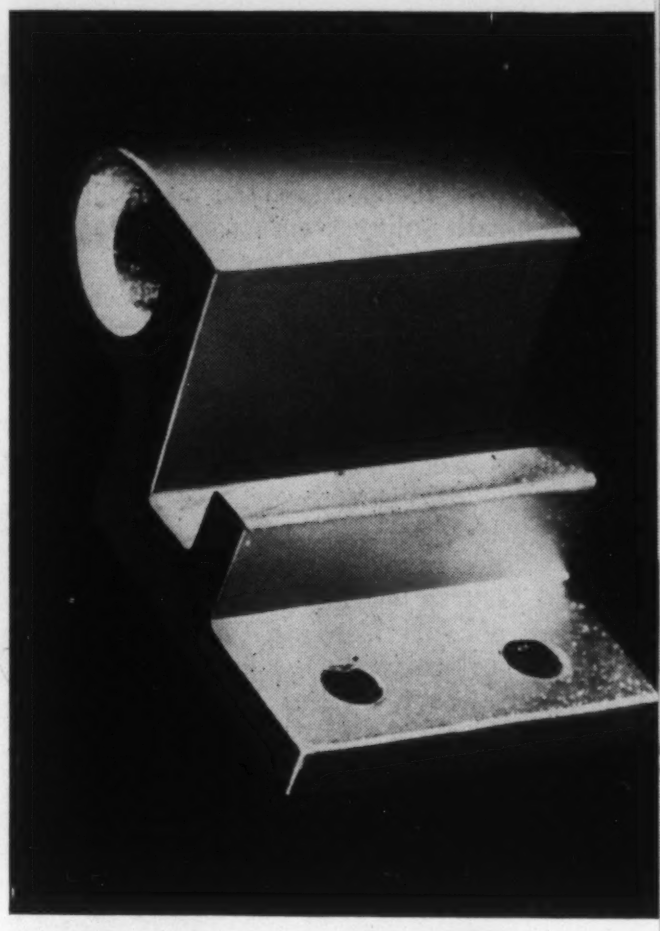
Cost

Up to now, "electroless" nickel plating has been generally regarded as costly compared to electroplating. Men working closely with the process agreed that it could be economically compared to silver plating.

The Kanigen Div., on the other hand, says its new process can beat electroplating cost-wise except for thick plates. And, with the "zero porosity" demonstrated by ½-mil "Kanigen" plates, they say, thick plates would seldom be necessary. The break-even point, in comparison to electroplating, is estimated to be thicknesses between 1 and 2 mils, depending upon the complexity of the part.

Improved economy in the "Kanigen" process has reportedly been achieved by reductions in both operating and fixed costs. A higher plating rate now possible increases production per unit installation, thereby reducing the portion of the fixed cost chargeable to each part processed in a continuous operation. And "zero porosity" enables the Kanigen Div. to use a plate of lower minimum thickness for a given job of corrosion protection, thus cutting the cost of chemicals needed for each part, as well as contributing to the speed of the process.

All "electroless" processes benefit from the uniformity of the plate which allows less nickel to be used for a given minimum thickness. Other economic advantages over electroplating are: (1) no electrical equipment required, (2) less operating labor required, and (3) no machining of anodes for special applications.



ALUMINUM hinge has a 2-mil coating. Adhesion of electroless nickel plate is good on most materials, but it is more difficult to obtain on aluminum than steel and brass.

Where corrosion protection of the kind afforded by nickel is economically justified and electroplating is not feasible, of course, the cost of "electroless" plating is not too important a factor. It is in such cases that older and relatively expensive "electroless" processes have already established themselves in many plants.

The relatively high price of hypophosphite salts has been an important economic obstacle for the "electroless" processes. Present indications are that these salts will soon be available at a price markedly lower than in the past.

How Process Works

A clean metal surface is just as important for satisfactory "electroless" plating as it is for electroplating. For this reason, the same steps in surface preparation which are followed prior to electroplating are recommended in connection with the nonelectrolytic method. Since many organic compounds have a deleterious effect upon the plating bath, the use of organic cleaning compounds immediately prior to plating is not advised.

The suitably prepared metal is immersed in the chemical bath which is held at a temperature near 210 F to speed the chemical reaction and keep the rate of metal deposition as high as possible. As is the case in any surface reaction, plating speed is further increased if the metal and the bath solution are in motion with respect to each other.

The chemical reaction which takes place is essentially the reduction of a nickel salt to metallic nickel, with accompanying formation of acid. The best yield obtained by Brenner and Riddell, based on conversion of hypophosphite to phosphite, was 37%. This means it takes a minimum of 5.5 lb of the sodium hyposphosphite salt to deposit each pound of nickel-phosphorus plate. It is understood that this yield has been boosted considerably in the "Kanigen" process.

The plating rate varies with pH level as determined by bath composition. In most of the baths now operating, the rate of metal deposition does not exceed 0.0005 in. per hr. However, developers of the "Kanigen" process say that, although their rate does not compare with a high-speed electroplating bath, it is roughly equivalent to that used for "a good quality electroplate". This would indicate a rate of 1 to 2 mils per hr. Rates of this same order have been obtained by at least one investigator with a bath similar to that of Brenner and Riddell. Some idea of bath capacity is given by the original recommendation of Brenner and Riddell that no more than 0.5 sq ft per gal be plated at one time.

The most important feature of the process, in comparison with electroplating, is the absence of the factor known as "throwing power". The electroplater must be concerned with the relative placement of the part and anode in order to assure a fair degree of uniformity in metal deposition, but it would be impractical to use anodes of the number and shape necessary to achieve the kind of uniformity provided by a chemical process.

In the case of copper and brass, which are noncatalytic to the process, one of two special techniques must be used: (1) the surface must first be dipped in a solution of a catalytic metal such as palladium, or (2) it must be in contact with a catalytic metal such as steel or aluminum while immersed until plating out begins. The latter technique is also used to start plating out on semiconductors, such as graphite, silicon carbon, etc.

The Plating Bath

The plating bath itself consists of a water solution of three principal ingredients: a nickel salt, a hypophosphite salt and a buffer.

The nickel salt can be either the sulfate or the chloride. Nickel sulfate is the cheaper by a slight margin and may promote a somewhat faster plating rate. Nickel chloride, on the other hand, seems to give a slightly brighter plate.

Sodium hypophosphite is the most common reducing agent used, although use of calcium and other hypophosphites has also been reported. Both reacting salts must be replenished as the process continues.

For an alkaline bath, sodium citrate is used as the buffer and ammonium chloride is included as a complex-ion-forming compound necessary to keep metal ions in solution. Chief disadvantage of the alkaline bath is its low plating rate and the discomfort caused by free ammonia fumes.

Maximum plating rate seems to occur at a pH in the range from 4.5 to 6. To maintain the bath at this degree of acidity, sodium hydroxyacetate is commonly used. The effectiveness of this buffer, which also forms complex ions, is not all it might be, however, and many attempts have been made to find a better one. Although most such attempts have been unsucessful, it is understood that the "Kanigen" proccess *does* utilize a different buffer.

The following bath compositions, developed by Brenner and Riddell seven years ago, are basically those which are in widest use today:

Alkaline Bath

	Oz per Gal
Nickel chloride $NiCl_2$-$6H_2O$)	4
Sodium hypophosphite	1.3
Ammonium chloride	6.7
Sodium citrate	13.4

Acid Bath

Nickel chloride	4
Sodium hypophosphite	1.3
Sodium hydroxyacetate	6.7
Brighteners (optional)	—

The bath composition used in the "Kanigen" process has not been disclosed, and it is possible that important changes may have been made in addition to the difference in buffers used.

Principal equipment needed for bath is a source of heat and a vessel. The vessel can be made of glass, porcelain, enamel, ceramics or of metal lined with an envelope of polyethylene sheet. The latter may offer an important advantage in that the sheet can be removed when it becomes overly contaminated by small but unavoidable nickel deposits. The Kanigen Div. says additional special equipment is required to produce a plate of the quality it claims for "Kanigen".

Availability

There are three avenues open to the company wishing to make use of "electroless" nickel plate:

1. To design an installation suitable for the particular application based on the Bureau of Standard's process. Several large companies have done this. An example is the Wright Aeronautical Div. of Curtiss-Wright, which is plating grooves on aluminum pistons in a beaker set-up. Another is Eastman Kodak, which is plating the interior of diffusing pumps. It is understood that the process can be licensed royalty-free from the U. S. Dept. of Commerce.

2. To draw upon the several years' experience of one of several small companies who make a business of packaging and selling chemicals specifically for "electroless" plating. A pioneer in this effort is the Metal Processing Co., of Cedar Grove, N. J., which has supervised the installation of the process in several large plants, including those of General Electric, Thompson Products and American Metal Products.

3. To subcontract its plating work to the Kanigen Div. of General American Transportation Corp., which expects to have plants operating in East Chicago, Ind., and Los Angeles, Calif., in a couple of months. Later on, the Kanigen Div. has announced, it will license its process to interested firms.

Acknowledgment

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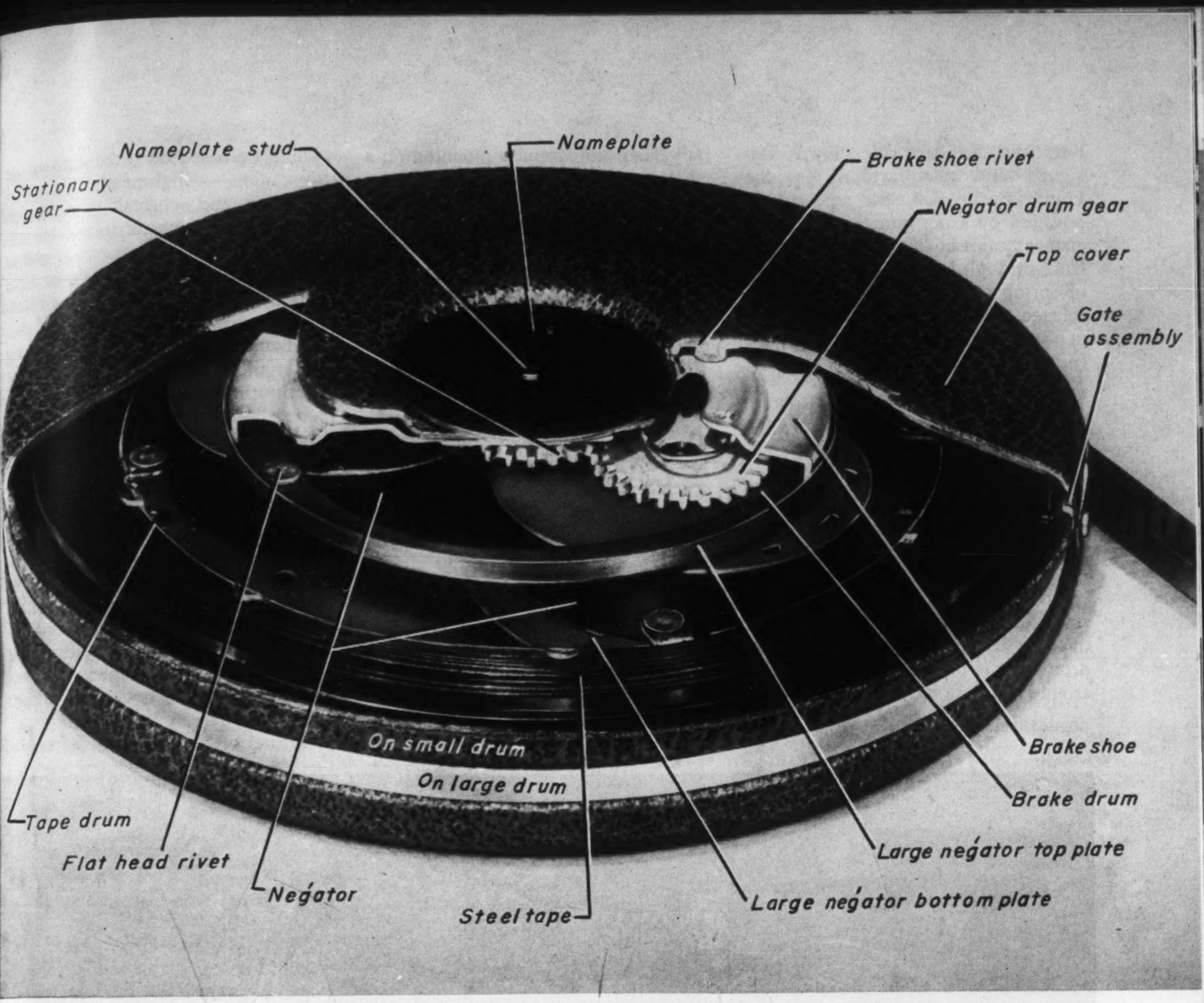
PICTURE CREDITS: Kanigen Div., General American Transportation Corp.; Wright Aeronautical Div.


Nameplate stud
Nameplate
Brake shoe rivet
Stationary gear
Negator drum gear
Top cover
Gate assembly
On small drum
On large drum
Brake shoe
Brake drum
Tape drum
Flat head rivet
Negator
Large negator top plate
Steel tape
Large negator bottom plate

Cut-away view of self-retracting steel tape rule. Lightness, strength and corrosion resistance were considered in selecting the materials.

Selecting Materials for Small Assemblies

by **LEO B. GLASER**, Manager, Neg'ator Div., Hunter Spring Co.

Intelligent materials selection in the design stage leads to economical fabrication of small assemblies.

● A COMMON APPROACH in the design of small assemblies is to determine first the shape and size of components and then select the materials. Most engineers responsible for designing such assemblies can recall products which were designed rapidly and with a great sense of accomplishment, tested in operation and then subjected to frequent changes in materials through many months. The most appropriate materials are eventually discovered, performance is highly successful, and nothing is lost but many dollars of engineering time and production delay. Certain changes in materials, like changes in design, are inevitable. However, the application of some intelligent materials engineering early in the design stage can produce as good or better a product at less cost.

The most common elements of materials engineering in the design of simple mechanical assemblies can be illustrated by the selection of materials for components of the 50-ft self-retracting steel tape rule shown. Designed and manufactured by the Hunter Spring Co., the tape rule is powered by a neg'ator, a mechanical element capable of exerting constant force through long distances. A strip of spring material stressed so that its relaxed form is a tight coil, the neg'ator produces a nearly constant force on the steel tape throughout the 50-ft retraction.

Description of Product

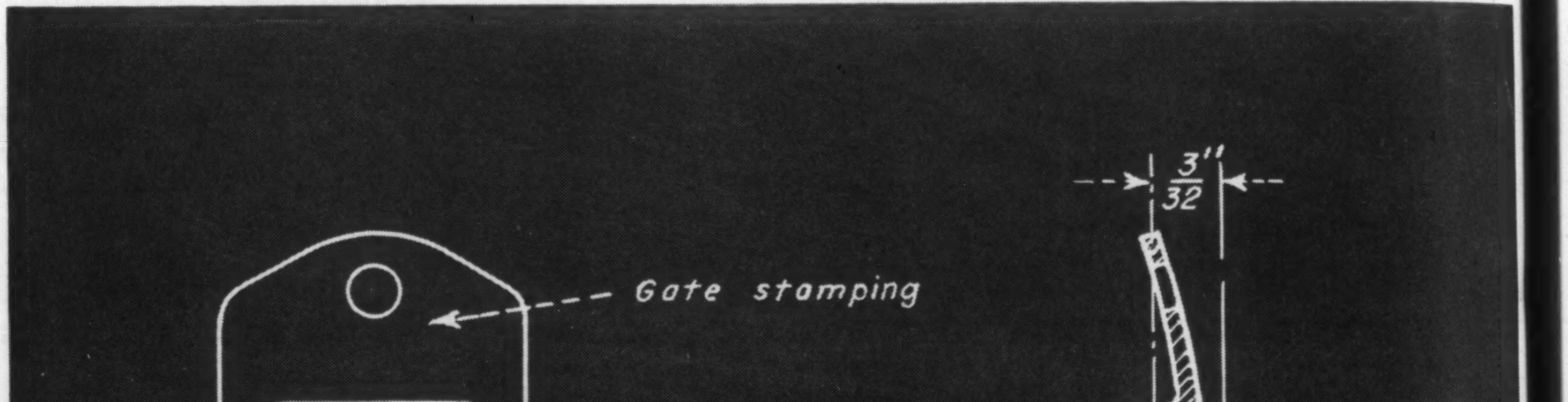
The neg'ator is mounted in its motor form on a small and a large drum. Torque is produced on the axis of the large drum as the neg'ator tends to run from its coiled, highly stressed condition on the large drum onto the small drum. In the planetary drive of the system of the rule, the neg'ator drum gear is driven counterclockwise around the stationary gear. Since the large neg'ator drum is mounted on a shaft between the top and bottom plates of the tape drum, the latter also rotates counterclockwise and the tape is retracted into the case. This action occurs when the nameplate is pressed down, forcing the brake shoe away from the brake drum. The neg'ator is wound from the small neg'ator drum onto the large neg'ator drum as the tape is pulled out of the rule.

The basic units of the rule are: (1) cover assembly; (2) tape drum assembly; (3) large neg'ator drum assembly; (4) small neg'ator drum assembly; (5) braking mechanism (including nameplate, brake shoe, brake drum); and (6) gate assembly.

Aims in Selecting Materials

Before actual design began, it was known that selection of materials and methods of assembling these units would be based on three general design aims — lightness, mechanical strength and corrosion resistance. These three characteristics were important because the tape rule was to be carried for long periods of time and would be exposed to rough handling and moisture in the field.

Stamping, machining and casting were three methods available for forming various components in the rule. All drum assemblies and the brake might have been screw-machine parts. The brake shoe might have been a casting. However, the Neg'ator Div. planned to produce a large quantity of rules at a low unit cost and stampings have been used wherever possible. Although involving a higher initial investment than required in the production of similar screw-machine parts on smaller quantities, the total cost was lower per unit produced. The only screw-machine parts



Detail of stamping and rollers making up gate assembly.

in the tape rule are two studs, two rivets and three shafts. As will be evident, the selection of stampings had considerable bearing on the materials used to obtain thin, light sections of rigid construction.

The eight materials used in the rule are: full and half-hard aluminum; Types 302 and 303 stainless steel; cadmium-plated cold-rolled steel; terne-plated steel; brass and nickel-plated brass. All components are corrosion resistant, in varying degrees, and as many as possible are made of aluminum. Within the framework of these requirements, a prarticular material was selected for one or more of the following reasons: (1) compatibility with other materials with respect to seizing or galling or electrolytic action; (2) loading; (3) wear and abrasion; (4) appearance; (5) machinability; (6) workability; (7) standard components available; and (8) adhesion properties. Relative cost was considered in selecting materials for all components. Wherever two materials proved to be equally satisfactory, the less expensive material was specified.

Compatibility

The brake drum is normally loaded by the brake shoe, which is cadmium-plated cold-rolled steel. Therefore, to avoid seizing or galling, the brake drum was stamped from 0.031-in. soft brass rather than from the same material as the shoe.

While the possibility of seizing between brake shoe and drum was readily predictable, the necessity for using terne-plated steel for the bottom plate of the large neg'ator drum was not determined until models were tested. It was found that a force on the large neg'ator drum shaft and forces between the two gears produced a resultant force on the shaft which made the large neg'ator bottom plate touch the bottom tape plate intermittently during operation. Originally, both components were aluminum and tended to seize. Because it is the smaller and thinner of the two components and would least increase total weight if made of a heavier material, the large neg'ator bottom plate was finally specified as 0.020-in. terne-plated steel, with cadmium-plated cold-rolled steel as a substitute. Although it is smaller and does not rub against the top tape plate, the large neg'ator top plate is also stamped from 0.020-in. terne-plated steel in the interests of production standardization.

Four flat-head rivets secure the brass brake drum to the top tape plate. Because of probable accumulation of moisture during use, the designers felt that the possibility of electrolytic action between these components must be eliminated. Therefore, the bottom of the brake drum is lacquered to prevent direct contact with the aluminum top tape-plate. The rivets are aluminum and are, therefore, compatible with this plate. After the drum and plate are riveted, the tops of the rivets are lacquered to prevent moisture from reaching the brass-aluminum contact surfaces.

A rivet secures each of the two brake-shoe segments to the top cover of the rule. Brass is used for these rivets since it is a material compatible with both the cadmium-plated cold-rolled steel brake shoes and the terne-plated steel top cover. Both the small neg'ator drum shaft and the shaft which secures the end of the tape itself are cadmium-plated cold-rolled steel, although stainless steel is a preferable material. However, both shafts are mounted between the aluminum top and bottom tape plates and it was necessary to eliminate the possibility of electrolytic action between the aluminum and stainless steel.

Loading and Abrasion

One of the several reasons for making the nameplate stud of stainless steel was the high load between the cam surfaces of the stud and the brake shoes.

Stampings for the small neg'ator drum assembly and the tape drum assembly are produced from full- and half-hard aluminum sheets. The small neg'ator drum assembly, for example, consists of: (1) drum shaft, (2) drum stamping, (3) top plate, and (4) bottom plate. The design is such that upon assembly the top and bottom plates are slightly dished inward to produce the desired pressure on the drum stamping. The tape drum and the large neg'ator drum are assembled in the same manner. The top and bottom plates of the small neg'ator drum and tape drum are full-hard aluminum to avoid permanent deformation when dished. However, the drum stampings are half-hard aluminum because they are subject only to compressive loading, and this grade is easier to fabricate.

The two rollers in the gate assembly are Type 303 stainless steel to withstand repeated abrasion by sand and dirt as the tape runs in and out of the gate. Brass was considered too soft and a plated material too delicate for these parts.

Working and Machining

The gate stamping is not particularly easy to produce. The stamping is, therefore, made of brass to obtain the maximum depth of draw and workability. Similarly, terne-plated steel was considered a suitable material for the proper drawing of the top and bottom covers.

The maximum stock removal in all the machined parts occurs in the reduction of the diameter of the 0.060-in. exposed end of the nameplate stud from 0.250 to 0.114 in. The need for extra machinability was considered sufficient to justify the specification of selenium-bearing Type 303 stainless steel for this part. The stud was also passivated to clean the exposed surface and for improved appearance and corrosion resistance.

Standard Sizes and Appearance

Both the stationary gear and the neg'ator drum gear are standard gears (pitch dia is 0.750 in., 24 teeth) of cadmium-plated SAE 1010 steel. Stainless steel would have been equally satisfactory, had it been available in standard sizes.

The two shafts illustrated in an accompanying figure are sections of tubing so that they may be staked into the gate stamping. Although most appropriate from an appearance standpoint, stainless steel tubing is not available in the required size, ⅛-in. o.d. and 0.032-in. wall thickness, and both shafts are 0.400-in. lengths of brass tubing.

Although made of brass to provide greater machinability, the gate stamping is nickel-plated to improve the appearance. The gate shafts, with only a small portion visible at either end of the rollers, were nickel-plated for the same reason.

Adhesion Properties

In selecting a material for the top and bottom covers of the tape rule, it was necessary to obtain good adhesion of the fabricoid cover as well as workability, minimum cost, and corrosion resistance at exposed surfaces. Plating was unsatisfactory because of the high cost and, in addition, a plated surface was not acceptable for effective adhesion of the fabricoid cover. Therefore, terne-plated steel was selected as best fulfilling all basic requirements.

WEAR RESISTANCE *of the new polyester synthetic rubber may make possible tires that outlast life of car itself. This tire, made of the new synthetic and sections of highest quality natural-synthetic rubber stock, has traveled 5000 miles.*

by **KENNETH ROSE,**
Mid-Western Editor,
Materials & Methods

Two New Synthetic Rubbers

—They Offer

- ***Excellent Chemical Resistance***
- ***Long Wear Life***
- ***High Toughness and Flexibility***

● TWO NEW SYNTHETIC elastomers are now available in limited quantity to industry, one a product of E. I. du Pont de Nemours & Co., Inc., the other offered by Goodyear Tire and Rubber Co. Although quite dissimilar chemically, both are based upon ethylene, and so are quite different from the standard synthetic rubbers. They are chemical derivatives of the same base as that of polyethylene plastic, the material that has made an important place for itself as a film in wrappings, food containers and electrical insulation, and as a molded material in chemical containers, squeezable bottles, and unbreakable tableware. The du Pont material has been designated "Hypalon". The Goodyear product has not yet been named.

Hypalon is a chlorosulfonated

CHEMICAL RESISTANCE *of the new chlorosulfonated polyethylene elastomer is demonstrated here. Hypalon in the top hand retains original size and flexibility, but natural rubber in bottom hand swells 400 to 500% after immersion in liquid chlorine for 24 hr.*

polyethylene, while the Goodyear elastomer is a polyester based upon ethylene and proplyene and adipic acid. A di-isocyanate is used with the latter material as a blocking agent to stop the combination of the chemicals at the desired physical consistency for best workability.

DuPont's Hypalon

Hypalon chlorosulfonated polyethylene now in semi-commercial production, is unaffected by ozone, has excellent chemical resistance, abrasion resistance equal or superior to the best GR-S synthetic rubber, fair oil resistance, and good dielectric properties. It possesses excellent flex-life, good flexibility at –65 F without plasticizers, and good elevated temperature characteristics in continuous service up to 250 F. It can be used for intermittent service at even higher temperatures. Because it needs no carbon black for reinforcement, it has an unlimited range of color possibilities.

Although the elastomer has very low water absorption, and is not hygroscopic, it is sensitive to moisture, and should be kept dry during storage. Storage life is given as six months minimum during hot and humid weather, and probably much longer during average conditions.

As Hypalon is compatible with natural rubber, and with GR-S, acrylonitrile, chloroprene and butyl synthetic rubbers, it can be used to improve the ozone resistance, chemical resistance, and abrasion resistance of these other elastomers. Elevated temperature resistance can also be improved for most of them.

Vulcanizates of Hypalon can be produced with a combination of metal oxides, sulfur-containing accelerators, and organic acids. Properties of the resulting vulcanizate vary somewhat with the type of curing agent used. Some of these agents, and the results they produce, are given in the following list:

Curing Agent	*Kind of Cure Resulting*
Magnesium oxide	Very good, but with relatively high water absorption
Litharge	Excellent; discolors in sunlight
Red oxide of lead	Fair; low tensile strength
Antimony trioxide	Poor
Zinc oxide	Poor; poor aging characteristics
Aluminum oxide	Fair; water-sensitive
Barium oxide	Poor
Calcium oxide	Fair; slow cure
Titanium dioxide	Poor; little or no cure results
Ferric oxide	Poor; little curing action
Dibasic lead phosphate	Good; sensitive to heat and pressure
Monohydrous tribasic lead sulphate	Good; discolors in sunlight
Tribasic lead maleate	Very good

Of these, magnesium oxide, litharge and tribasic lead maleate have been given the greatest amount of study. From 2 to 6% of the volume of elastomer seems to be the optimum quantity of curing agent.

Hypalon can also be vulcanized by use of organic curing agents, such as many diamines, ureas and thioureas, amides, thioamides, carbamates and thiocarbamates, isocyanates, oximes, nitroso-compounds and thiozoles. Metal oxides, however, produce vulcanizates less sensitive to water. Both carbon black and whiting can be used as fillers, along with clay and other organic and inorganic materials. The new elastomer develops good properties even in the absence of carbon black reinforcement, however, whereas natural rubber and some other elastomers require such reinforcement for maximum properties.

The material before cure is a rubbery, rather tacky substance, with a specific gravity of about 1.1. Resistance to ultraviolet light is improved by formulating with materials that will serve as a screen for the ultraviolet radiation.

The material at present is high in cost, but du Pont believes that for demonstrated uses, it will be competitive. The future price, of course, depends on future construction, labor and ingredient costs. Du Pont is optimistic about those, and assuming full commercial production is warranted, the current price of $1.10 per lb will be sharply reduced.

The excellent chemical resistance of the elastomer seems to indicate possibilities as a tank lining material. It resists attack by concentrated sulfuric, nitric, hydrochloric, chromic and other strong oxidizing acids and compounds. It is being used experimentally in tire sidewalls, where its high ozone resistance, good flex-life, abrasion resistance and wide color possibilities are an advantage. White sidewall tires and colored sidewall tires that harmonize with the body color are now under test. Colored weatherstripping in automobiles is also being considered. For colored floor mats in cars, the high abrasion resistance is of importance also. Other possible uses that are under test or are being considered are as a coating for electrical conductors, as a material for acid hose, and as a protective coating for rubber and fabrics.

Goodyear's Elastomer

The new polyester synthetic rubber announced by Goodyear Co. has as its special properties greatly improved resistance to abrasion and much greater toughness than present synthetics. Laboratory work indicates, the company reports, that an automobile tire made of the new synthetic might outwear the car itself. Heavy-duty conveyor belts, shoe soles and heels, tire treads, and other products requiring best abrasion resistance are probable applications.

The Goodyear polyester rubber, not requiring carbon black for reinforcing, offers good color possibilities. It vulcanizes by use of an additional amount of di-isocyanate after the chemical formation of the material. Sulfur and accelerators are not used in vulcanization. Cure time is about half that of present rubbers.

Although similar to the new German synthetic rubber, Vulcollan, the Goodyear polyester has the important advantage of being processable on the usual rubber machinery. Vulcollan must be molded immediately after it is chemically constituted.

Oil resistance is fair, according to laboratory men who have tested the elastomer. Tensile strength is 50 to 100% better than that of any other elastomer. Resistance to oxidation is far superior to that of other elastomers. In air diffusion resistance it equals butyl rubber, the best of the elastomers in this respect. Tire treads made with the polyester show wear resistance two to five times greater than that of the best rubber produced by cold polymerization.

At present, production is not sufficient for any but test purposes. Work is being done to overcome processing difficulties, and to improve present resilience and adhesion. This compound, like the du Pont product, is covered by patents.

Chromizing Improves Surface Properties of Steels

by **RICHARD P. SEELIG, Executive Vice President, Chromalloy Corp. of N. Y.**

Heating parts in special powder compound produces surface layers of either high chromium or chromium carbide content. Process is applicable to low carbon steels, many types of alloy steel, high chromium and other stainless steels.

● HIGH CHROMIUM ALLOYS are widely used in industry for corrosion resisting and elevated temperature service. Since corrosion and oxidation resistance are surface properties, full resistance for many applications can be achieved by confining the chromium content to a relatively thin surface layer. Various methods for the impregnation of steels with chromium have been developed, among the most successful being the Chromalloy process.

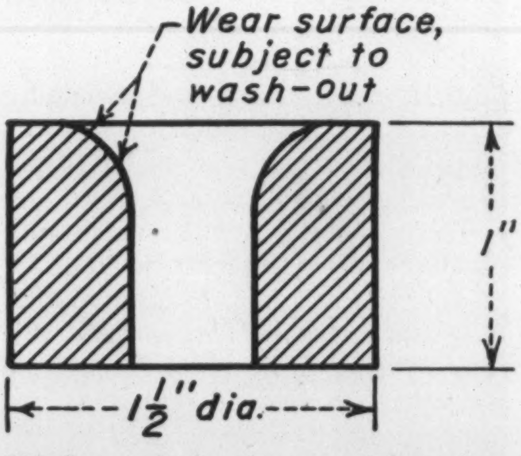
The Chromalloy process uses a reaction between a gaseous chromium compound and iron as a means of exchanging iron atoms for chromium at the surface of the steel. This is accomplished by packing the parts to be treated in a patented powdered compound, containing chromium, an energizer and an inert material.

This process does not apply a coating nor does it plate or deposit a film on the ferrous metal surface. Instead, it transforms the steel surface into either high chromium stainless steel or chromium carbide. Which one of these products is produced exclusively or predominantly depends mainly on the composition of the steel being chromized and the treatment selected.

The chromizing treatment can (1) improve the oxidation, corrosion and wear resistance of low carbon and many types of alloy steel, high chromium and other stainless steels; (2) increase the wear resistance of cast iron, tool steels and iron powder parts; (3) reduce material costs by eliminating the need for highly alloyed steels; (4) cut costs by replacing two or more heat treatments by one chromizing operation; (5) save fabrication costs; (6) conserve critical materials; and (7) improve the appearance of ferrous products.

Properties of the Case

To produce a Chromalloy case, the work and the chromium compound are enclosed in a hermetically sealed retort and heated to a temperature where the exchange reaction takes place speedily and where diffusion of chromium into the steel proceeds at a relatively rapid rate. This temperature varies between 1650 and 2100 F, depending upon the material to be treated and on the properties of the case desired (wear, corrosion or oxidation resistance). The time at temperature ranges from 2 to many hours.



Dimpling tools for sheet metal have been chromized to eliminate or reduce "wash-out" and replace carbide tools.

Case Composition—The chromium concentration varies with the distance from the surface. The actual chromium content at the surface can be varied to some extent and is usually about 40 to 50%, but the chromium content tapers off more or less gradually, depending upon the thickness of the case. The chromium content of the case which has been removed from the core (by dissolving the latter in nitric acid) is usually in the neighborhood of 24%. This may be considered as the average composition of the case.

Upon examination of an etched surface under the microscope, a dividing line is observed which represents the interface between austenite and ferrite at the chromizing temperature. It will be remembered that chromium alloyed in iron will suppress the austenite transformation entirely by closing the gamma loop. The line develops at approximately the 13% chromium level. It results from the different etching characteristics of the steel on either side. The chromium concentration, which tapers off gradually through the core, drops more sharply below the line. The alloy below this line possesses much less resistance to the etch than the case. The depth of case is usually reported as the distance from the surface to the apparent dividing line.

The speed of penetration is controlled by two mechanisms: the exchange reaction of chromium and iron, and the diffusion of chromium into steel and of iron through the chromized case.

Only the first is controlled directly by the chromizing method. Gaseous reaction is superior to other procedures because of the rapid replacement of chromium atoms for iron atoms since the latter are removed continually as a gaseous compound. The second reaction is in no way affected by the particular chromizing method but depends only on the rate of diffusion of chromium into iron. By moving chromium into the interior and iron to the surface, it assures the continuation of the exchange reaction.

Case Thickness—The thickness of the chromized case is a function of surface condition, temperature of treatment, time at temperature, carbon content of the steel, and alloying elements.

The surface should be smooth and clean. Grease and oil are usually removed by degreasing prior to chromizing. Scale and rust are removed mechanically or by pickling. A small amount of rust or tarnish does not interfere with the reaction because the reducing atmosphere takes care of them automatically.

Raising the temperature accelerates both the exchange reaction and the diffusion rate. However, high processing temperatures can result in grain growth and distortion of the steel. Other undesirable features of high processing temperatures are shortened retort life and sintering of the compound. It is, therefore, desirable to balance temperature against time with the aim of obtaining the optimum conditions for economical operation.

Carbon strongly retards the diffusion of chromium into steel. Where a thick case is desired, low carbon steel should be selected. If medium or high carbon steel is essential to obtain desired core properties, the surface of the parts can be decarburized before or during the chromizing operation to promote penetration.

It is possible to compensate to some extent for the effect of carbon by suitable alloying additions. Elements which tie up carbon during chromizing promote deep penetration. Alloying elements also influence the lattice structure of steel which, in turn, has a profound effect on the diffusion rate. Diffusion through ferrite is much more rapid than through austenite. Consequently, alloying additions which favor ferrite retention at chromizing temperatures help while austenite forming additions hinder chromium penetration.

One of the major advantages of the process is the fact that the reactive gas penetrates every hole, slot or other opening which is connected to the outside surface. This includes pores in iron powder parts. A typical example of such an application is illustrated. This unlimited throwing power has also led to some applications where plating would otherwise have been satisfactory. Uniform penetration is secured in the outside surface and in the roots of threads, in the inside of long tubing, and around the edges of outside and inside corners. Except in rare cases, no build-up results at corners.

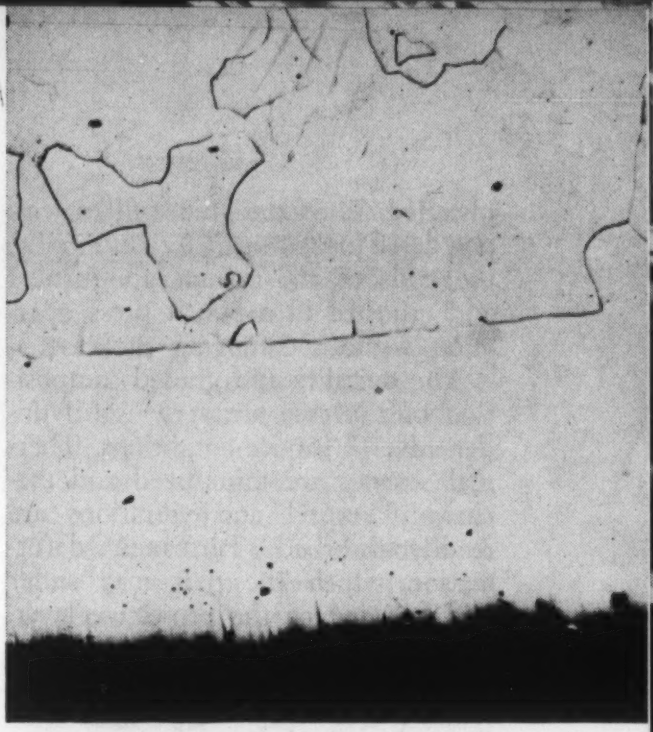
Hardness and Wear—If processing conditions are adjusted so that only high-chromium-iron alloy is formed, the hardness and wear properties of the case are comparable to those of fully annealed chromium stainless steel of the 400 series. On the other hand, the formation of chromium carbide results in hardness and frictional characteristics typical of this compound. Microhardness readings of 1500 to 1800 Vickers are obtained. Knoop values of around 1373 are obtained on chromized high-carbon high-chromium steel.

Dimpling tools for piercing and drawing sheet steel have been chromized to determine the usefulness of this treatment. The formation of the hard skin on this steel by the chromium carbide reaction is expected to eliminate or reduce "wash-out" and to obviate the need for tungsten carbide tools in this application.

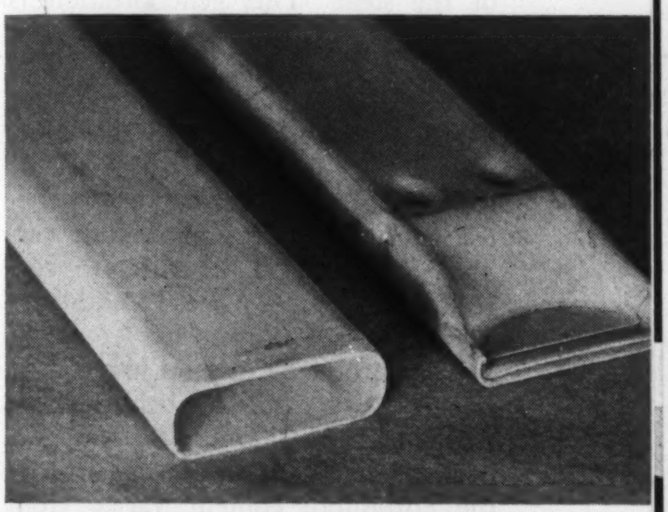
The usefulness of the chromium carbide surface treatment is not confined to the metal industry. The favorable wear and friction characteristics in contact with plastics, synthetic materials, paper products and other nonmetallic materials are being tested in a number of operations.

Ductility—The chromium-iron alloy case has considerable ductility, a useful characteristic in many applications. It is coupled with the fact that the case has a graded chromium concentration which blends into the steel core, without a sharp transition. As a result, it is possibe to work and form chromized parts severely.

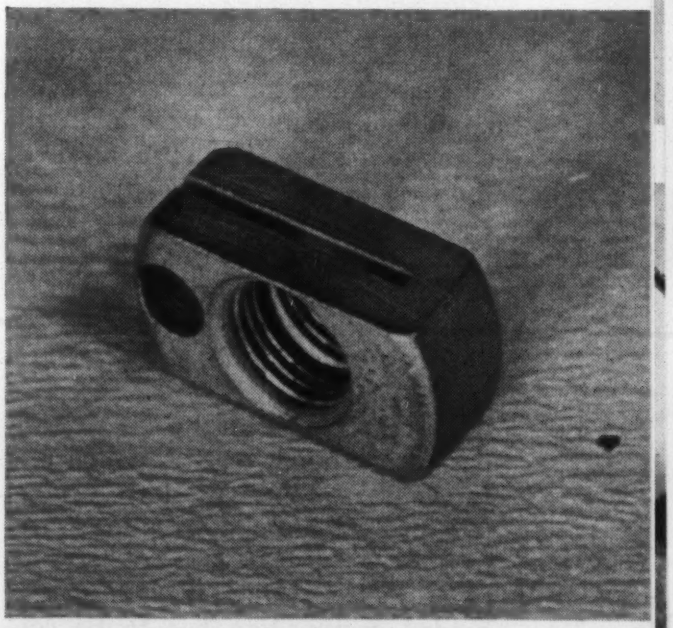
This quality is utilized in several commercial applications. For example, electric strip heater casings are chromized in the form of flat tubing, the heating elements are supported on insulators, and the terminals are



Typical case depth obtained on chromizing a very low carbon steel 200 X magnification.



The chromium-iron alloy case has sufficient ductility to permit chromizing of electric strip heater casings in the form of flat tubing and crimping the casings after filling with insulating material.



One of the major advantages of the process is the penetration of all openings by the reactive gas. Uniform penetration is obtained on outside surfaces and at the roots of threads.

installed. Then the unit is filled with powdered insulating material. Finally, the ends of the casings are formed and crimped in a punch press operation without damaging the case.

The ductility and graded composition of the case are very useful under adverse service conditions. Thermal stresses are minimized and mechanical impact and vibrations are readily absorbed. Permanent deformation which the part may suffer will not destroy the protective layer. These are essential advantages over sprayed, dipped or plated coatings.

Corrosion Resistance

It has been stated that the corrosion resistance of chromized steels is lower, the higher the carbon content of the steel. This generalization is not necessarily valid because of the many other factors involved. The influence of alloying elements may overshadow and outweigh the effect of carbon. In general, any set of conditions which favors deep penetration and reduces chromium carbide formation is beneficial to corrosion resistance. These conditions were discussed previously.

The chromized case on low-carbon steels resembles in its behavior the type 400-series stainless steels. However, it is important to recall that the chromium content varies from case to core. Because of this variation, the outermost surface resembles type 446 stainless; this is true for a very small depth only, however. At the line of demarkation, which under the microscope appears to be the end of the case, type 410 composition prevails.

There are other physical differences between the characteristics of chromium stainless steel and the chromized case. The satin finish of the case is very pleasing in appearance, but it is well known that a highly polished surface will display superior corrosion resistance under most conditions.

A comparison with plated surfaces is also enlightening. The fact that in chromizing we deal with an alloy has been brought out. A plated coat loses its usefulness suddenly when it is pierced through its entire thickness by corrosive or mechanical action. With a chromized layer, the graded composition has to be considered. Each fraction of a thousandth of an inch which is removed or penetrated exposes a lower grade alloy which has less resistance to the attack. A gradual reduction in effectiveness results. An important advantage is the density of the case and the fact that it cannot spall or peel off the base metal. In general, the corrosion of chromized steels resembles that of the corresponding chromium-stainless steels.

Chromalloyed steels are fully resistant to all kinds of atmosphere conditions, hot and cold water regardless of aeration, photographic chemicals, milk and related food products, nitric acid in all concentrations hot or cold, soap solutions, other alkalies, oils and petroleum products, steam up to high temperatures, molten salts such as cyanide, and molten metals such as lead, zinc and aluminum.

Cast iron, which has been considered one of the less favorable materials for chromizing, shows excellent rust resistance in aerated water after Chromalloying with or without subsequent heat treatment.

With properly selected steel composition and a deep alloy case, chromized parts can be used in contact with sea water, fruit juices, molten chloride salts and chloride solutions.

Heat Resistance

One of the most valuable attributes of chromized surfaces is their excellent resistance to heat. This applies to exposure in air and in other atmospheres, notably combustion gases. In this type of service, chromized cold rolled steel has replaced stainless steel in a number of fields.

Good service life can be expected of standard chromized low-carbon steel up to 1650 F. Up to 1200 F, the life is practically unlimited. Chromized parts can be used up to 1800 F for short time service in applications where mechanical stresses are low. For high temperature service, special alloy impregnation is used containing either aluminum or silicon, or both, plus chromium.

Effect on Base Metal

The processing temperatures vary widely, depending upon the composition of the base metal, section thickness and the desired characteristics. However, in all cases, the temperatures are sufficiently high and the cooling sufficiently slow to anneal the material completely.

The hardness of the case is not affected by the condition of the core. If the wear resisting type treatment is applied, a very hard skin of chromium carbide is formed on top of a dead soft base metal. In applications where frictional wear is involved without stresses, impact or vibratory loads, this situation serves well.

Where chromizing is used for corrosion or heat resistance, parts are also frequently used in the soft condition. In some instances, this presents an advantage in subsequent forming operations. If the parts have to carry heavy loads and the relatively high ductility and low strength are objectionable, heat treatments are used to compensate for the loss of cold working or to obtain even higher physical properties. This technique is used on bolts produced from type 1020 steel. After chromium diffusion the steel is fully annealed and not sufficiently strong to resist the torque involved in making the connection. Also as a result of the softness, the threads are easily squashed by the tapped hole, making it very difficult to break the connection. The tendency of the chromized surface to gall is also troublesome.

All these shortcomings are overcome by a simple heat treatment. The parts are heated to 1525 F and air cooled. The exact mechanism of hardening by this treatment has not been determined, but apparently the surface is sufficiently high in chromium to have air-hardening properties. Whatever the mechanism, after this treatment the strength of the steel is equal to that of the cold-worked material and the bolts are able to carry the desired loads while the threads do not collapse under the maximum wrench torque. The thin, tightly adhering oxide film formed during heating and cooling makes the surface completely resistant to seizing.

One of the advantages of chromizing is the fact that size changes, if any, are very small. Theoretically, at least, there is no volume change as a result of chromizing by the exchange reaction. Chromium atoms migrate into the lattice, replacing iron atoms which are removed in the form of a gaseous compound, and the size and weight of the chromium atom is very nearly the same as the iron atom. This is quite different from plating or other coating methods, where a layer of another material is added to the base metal.

However, there are other factors which interfere with ideal dimensional stability and which must be taken into account in chromizing practice. One such factor is the formation of chromium carbide, which occurs in the presence of appreciable amounts of carbon. Its volume is larger than that of the base steel, leading to an apparent build-up. This is rarely more than 0.001 or 0.002 in., but on close tool parts, allowance is required. Fortunately, the growth is not very sensitive to minor variations in the processing cycle and, therefore, is readily reproducible.

Another and more important influence results from the fact that the parts must be brought to relatively high temperatures in order to produce the exchange and diffusion reactions. During the operation any internal stresses are relieved, an allotropic transformation takes place, and the parts undergo some thermal expansion. Under these conditions it is too much to expect long shafts, slender pieces of tubing or complicated bulky castings to retain tool room tolerances. The situation is further complicated by the fact that the Chromalloy case is thin so that subsequent grinding cannot be used to compensate for dimensional changes.

There are several possibilities which help offset this limitation. Since the steel is fully annealed after treatment, it is easy to straighten parts which have warped. Close tolerances can be restored and, at the same time, some cold work can be induced by cold coining. This approach is under development for ball bearing separators. Parts of this type may be made as stampings from cold rolled low-carbon steel, cold formed, carburized and chromized. Thereafter, the parts can be cold coined and, if necessary, hardened.

On parts which are treated for wear resistance and surface hardness, the necessary allowance is made in the machine shop. Where tolerances are very close, a trial run is made to check dimensional changes very accurately. After the chromium carbide treatment, hardening usually follows. Any size changes in that operation must be included in the calculation. As a last step, a light lapping, burnishing or vapor blasting operation is recommended.

Where formed strip, sheet or tubing have to be held to close limits and where the soft heat and corrosion resistant Chromalloy case is produced, the entire forming operation should be scheduled to follow the treatment. In addition to the desired accuracy, this may result in considerable cost savings.

Many Chromalloyed precision parts do not require any special precautions or subsequent operations. Nuts with a 2-in. dia thread were treated without disturbing the class of fit. The tools mentioned earlier retain their dimensional tolerances through the chromizing process and subsequent heat treatments. Distortion is remarkably small, except in parts with a very unfavorable slenderness ratio. This is true because the parts are supported all around by the chromizing compound and are heated uniformly at a moderate rate.

In many applications, it is best to treat parts prior to assembly. Joining methods which do not damage the coating must be selected. Spot and seam welding are best suited. Fusion welding can readily be applied, using stainless steel welding rods. Chromized surfaces can readily be brazed. Soft solder does not wet the chromized surface and cannot be used with ordinary fluxes and procedures.

Costs

Considering the value added to the parts, the Chromalloy process is economical. The chromizing compound is quite expensive but is reusable if properly regenerated. For conventional custom chromizing operations, the cost is calculated on the basis of the volume occupied by the parts. The underlying thought is that each furnace must produce a given revenue for profitable operation of the plant. Thus, the bulkier the parts and the longer the total furnace time, the higher the cost.

For very large production runs, a more accurate cost calculation is made on the basis of the amount of regenerated compound used per part treated, the labor required for powder preparation, stacking the parts, sealing the retort, charging and unloading the furnace, cleaning the parts, inspection, shipping and handling. Fuel cost, retort depreciation, as well as general maintenance, supervision and overhead charges are also included.

The cost of the process depends on many factors, and it is not feasible to establish a universally applicable per pound cost figure. Each part must be calculated individually. The operation, in some respects, is similar to pack carburizing, but the compound is considerably more expensive. Chromizing is more complicated than barrel plating, but usually less expensive than hard chromium plating. It is probably more expensive than conventional surface hardening method (*e.g.* cyaniding), but it is more economical than hard surfacing.

The case which is rich in chromium carbide approaches, in some fields, the life of cemented tungsten carbide. Yet, the cost of a high carbon or tool steel part which is treated in this manner is much lower. Where Chromalloyed low carbon steel tubing is used for heat resistance, it competes successfully with chromium stainless steel.

The process is flexible and lends itself to small lots and mass production. The cost per unit varies widely with the quantities.

Applications

Applications of Chromalloyed parts which are in use or are under development include: Heat shields for arc lights, paint removers, rocket motors; die and tool components for forming operations in the automotive, zipper, spring fastener field; wear resistant structural parts for wire drawing machines, cam movements, textile equipment, synthetic material processing equipment; sheaths for electric unit heaters for use in air or liquids; nuts, bolts and other fasteners subject to heat in aircraft and other applications; gas burner shields and tips subject to heat and erosion by combustion gases; combustion chamber liners, exhaust parts and vanes for engines, rockets, guided missiles, etc.; powder metallurgy parts such as pole pieces and structural parts which are difficult or impossible to plate; steam turbine components subject to oxidation and steam erosion; auxiliary components for jet engines, such as valve parts, fittings, starter parts, compressor vanes etc. These are examples of the versatility of the Chromalloy process, which is expanding into new military and consumer applications.

Acknowledgment

Some of the technical information was supplied by Chromizing Corp. of Calif., North Hollywood, Calif.

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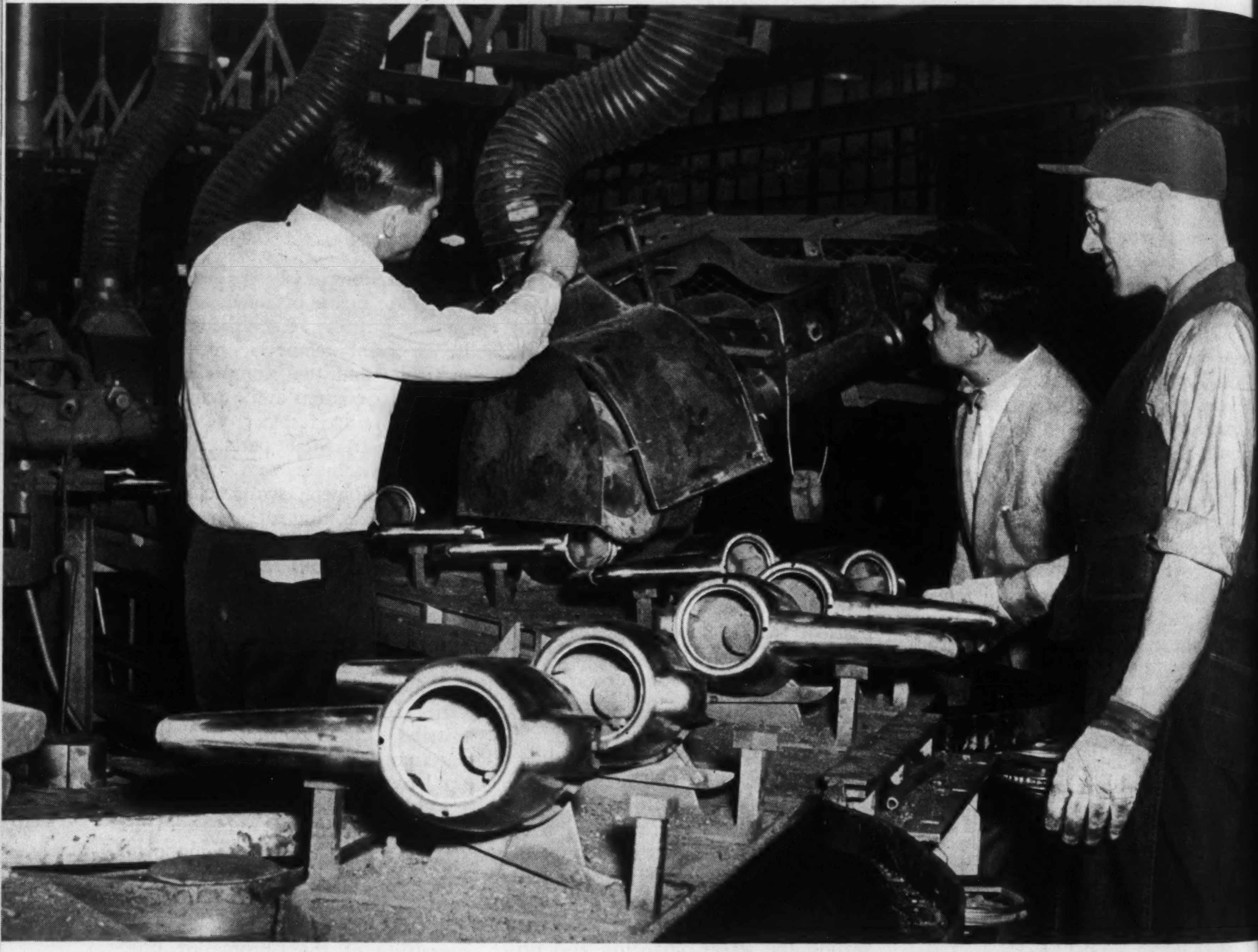
Materials at Work

Here is materials engineering in action . . .

New materials in their intended uses . . .

Older, basic materials in new applications . . .



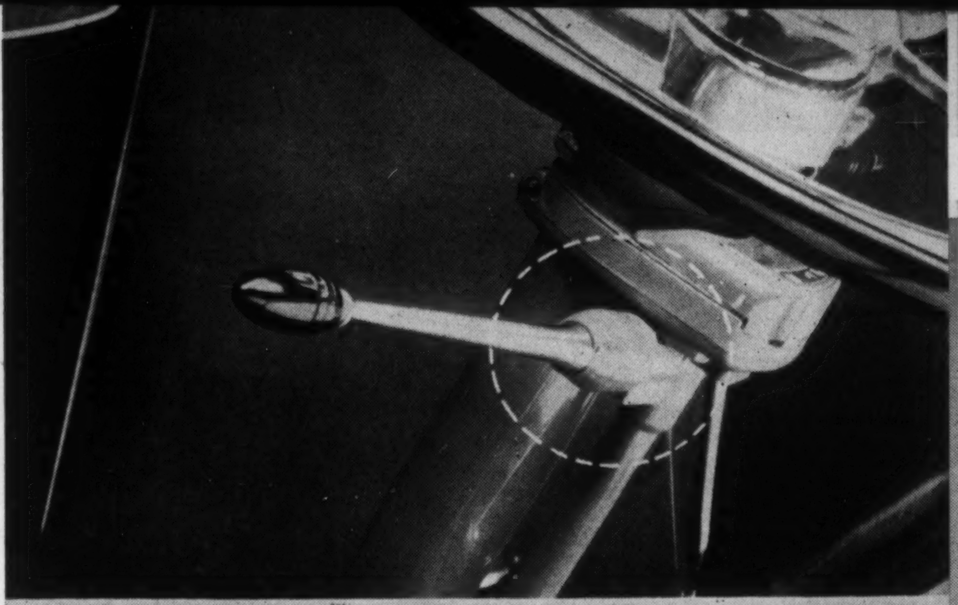
FLEXIBLE TUBING DUCTS Flexible ducts have increased production by 10% in the polishing and buffing department of A. S. Campbell Co. The ducts also get credit for reducing consumption of buffing wheels by about 15%.

Campbell makes automobile bumper guards for Ford, General Motors, Studebaker and other cars. After the bumpers are pressed out, they must be buffed and polished prior to electroplating. The company uses straight-line polishing machines, consisting of motor driven buffing wheels carefully balanced to apply just the right pressure on the work. Bumpers mounted on fixtures move down the line by chain conveyor, passing under one wheel after another. Each wheel is positioned to buff a different portion.

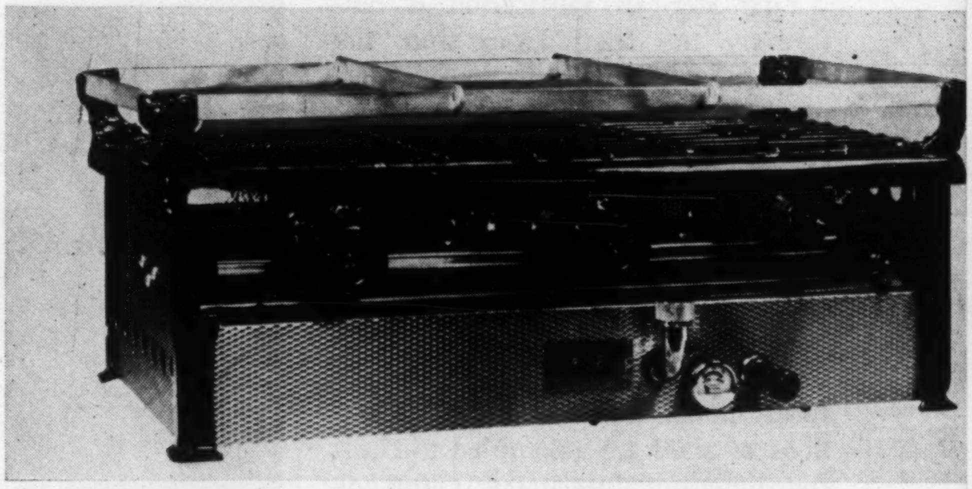
A flexible duct over the wheel draws off dirt and dust. Steel ducts were used originally. Rust and dirt in the spiral windings made them stiff within 6 months. Oil only caught more dirt. The stiff ducts were difficult to reposition when a different size or shape bumper was put into production. It often took as much as 3 hr to set up the line. Dust also built up inside the ducts to such an extent that fires started from sparks. Stiff ducts also caused trouble by preventing wheels from rising and falling smoothly across the work.

The solution was a Spiratube duct made of neoprene-coated fabric with a spiral wire sewn inside. The new ducts, supplied by Flexible Tubing Corp., are easy to adjust and offer no resistance to head movements. Dirt does not build up in the ducts, and no fires have occurred. They have been in service for 2½ years.

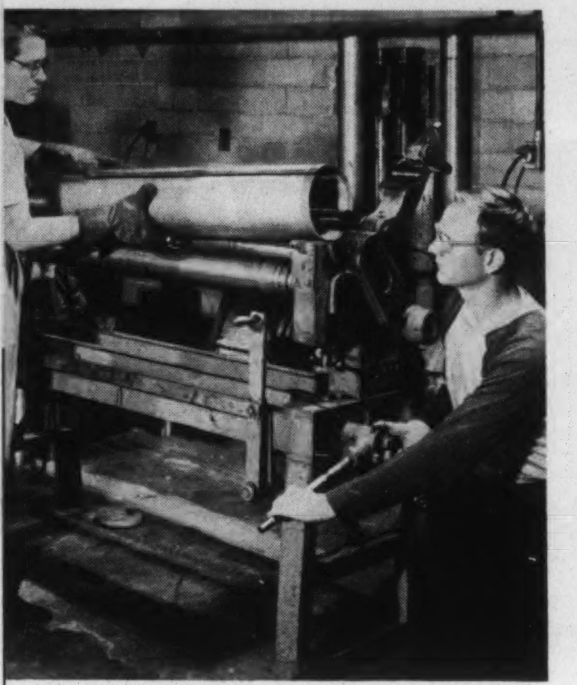
PLASTISOL GEAR SHIFT SHIELD Plastisols based on Bakelite Co. Vinylite resins make possible the development of a new type of protective shield for lever sockets controlling automatic transmissions on automobiles. Resistant to moisture, oils and greases, the plastisol covers seal out dust and moisture, and withstand continued exposure to sunlight without deteriorating. Covers can be accurately and economically color matched to the overall color scheme of car interiors. The resilient covers are easy to snap on and resist cracking, peeling or fading. An automatic precision dipping machine developed by the Watts Electric and Manufacturing Co. permits the production of this automotive part on a continuous line basis without the use of costly molding equipment that would be required to produce the same item out of rubber. The high-gloss plastisol based on Vinylite resins and having 100% solids content is supplied by Chemical Products Corp.

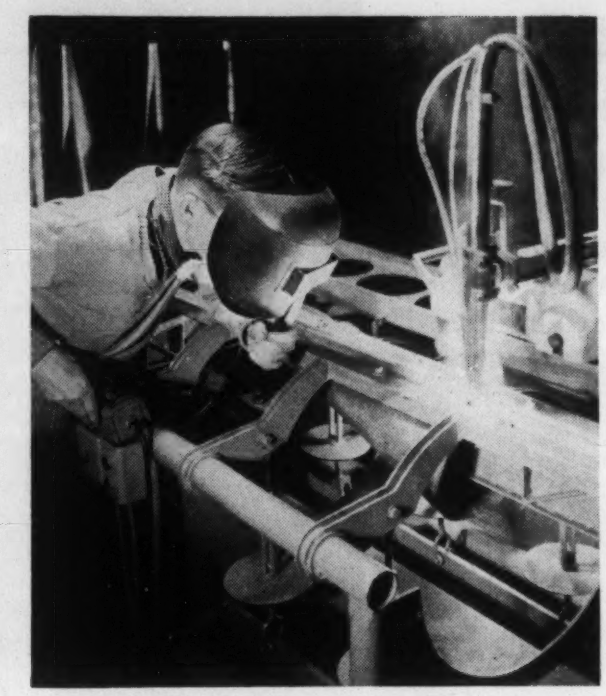


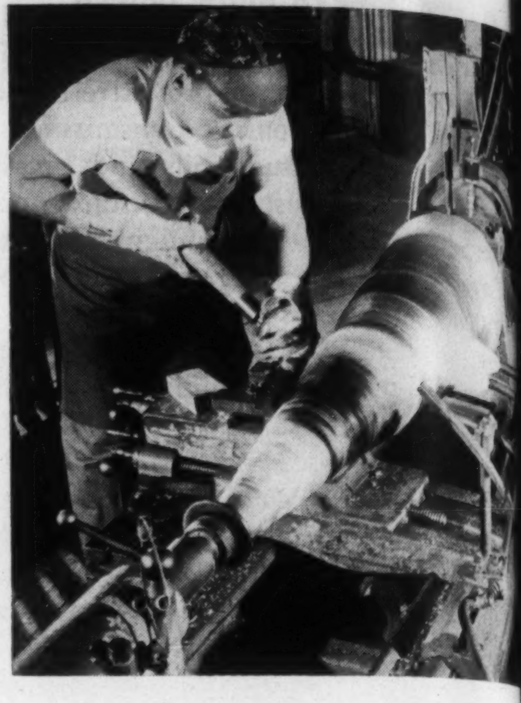
RIGIDIZED METAL STOVE BASE A high-strength base fabricated from textured Rigid-Tex Metal protects an alcohol stove made by Stanford Foundry Co. from shock or surface damage, yet still retains an attractive appearance. The stove is designed for use in a yacht galley. The Rigid-Tex Metal is supplied by Rigidized Metals Corp. The increased flexural rigidity of the material gives support to the stove without adding excess weight that might make portability difficult. During rough weather galley gear can clatter against the base without scratching or denting. The pattern conceals scuffs and even fingerprints.



GLASS WOOL INSULATION Microlite glass fiber insulation wool, made by Glass Fibers Inc., provided the solution to a design problem in this lighting fixture, made by Progress Manufacturing Co. Progress designers wanted to insure that high lamp temperatures would not damage the lead wires. They selected inorganic, heat resistant Microlite, in half-pound density, die-cut to the size of the opening in the top of the fixture. Holes for mounting screws were also die-cut. One-inch thickness of Microlite brought the maximum operating temperature of the leads down to 112 F, well within the specifications of Underwriters Laboratory.

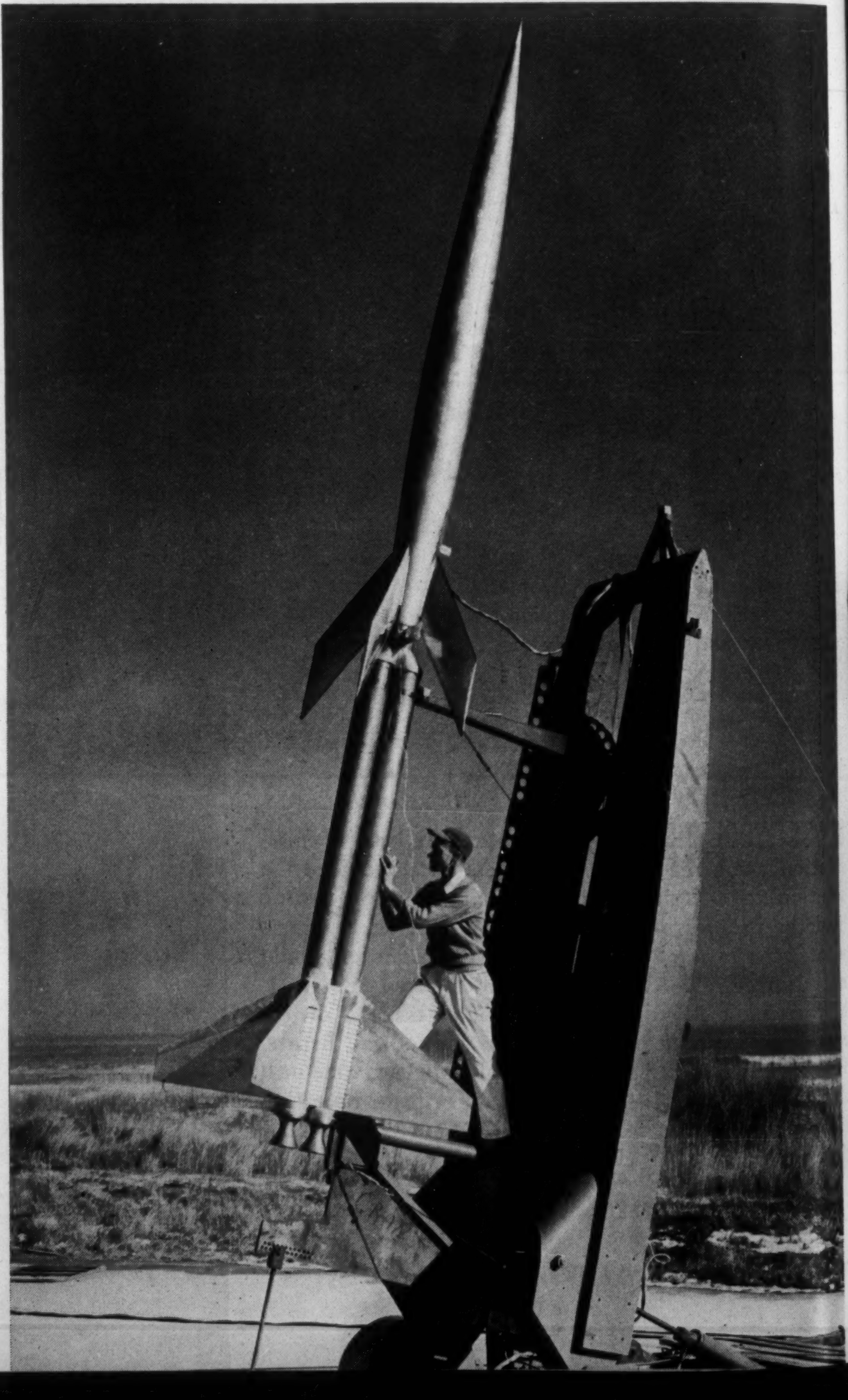


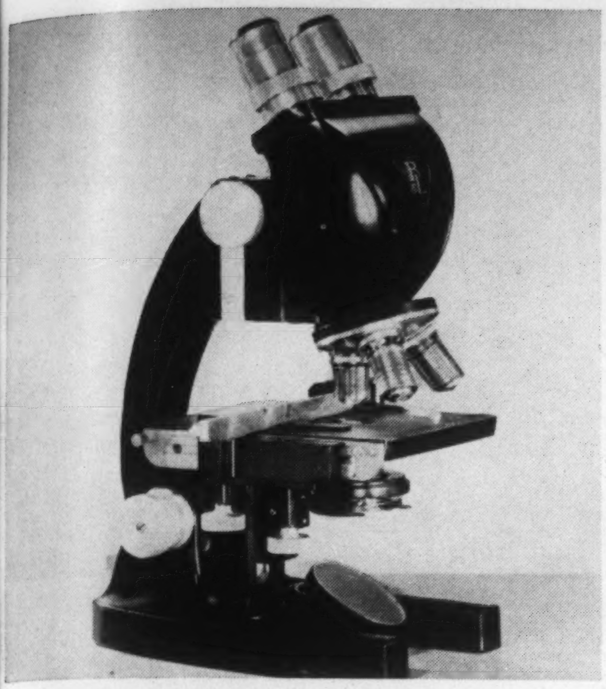


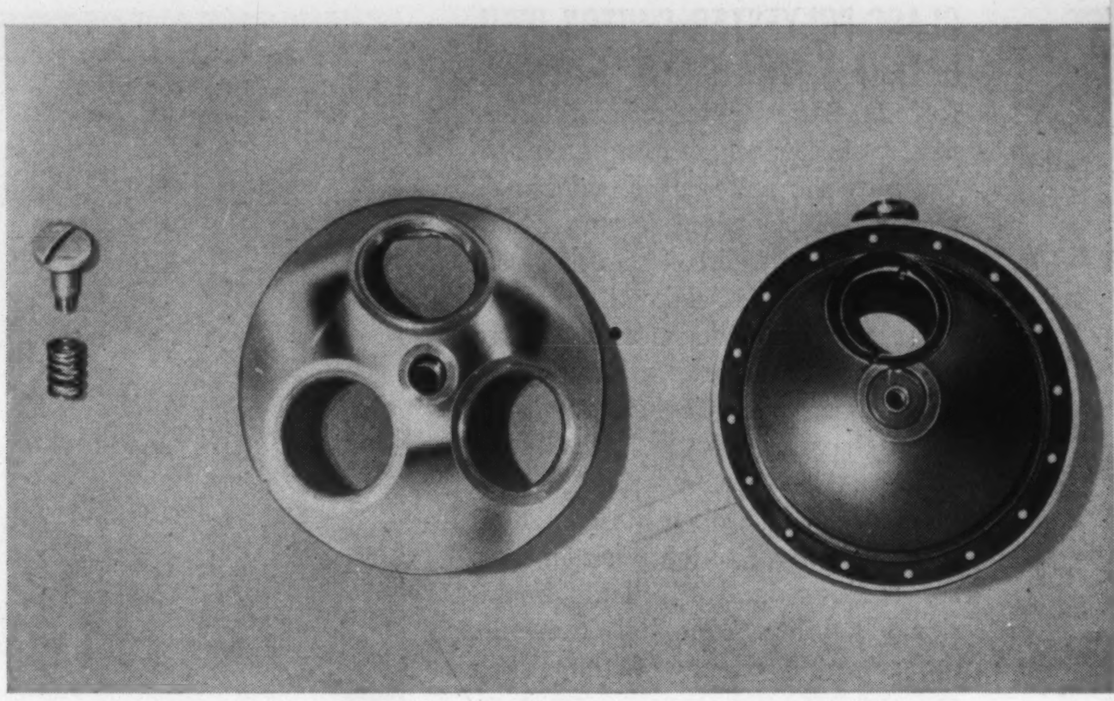


MAGNESIUM ROCKET Extensive use of rocket-propelled free-flight models, fabricated largely from magnesium alloy, enables the research scientists of the National Advisory Committee for Aeronautics to gather important aerodynamic information in the transonic and supersonic speed ranges.

First step in fabrication is hot-forming the shell from thin, flat magnesium sheet, using conventional pinch rolls. The shell may be made up of three or more sections formed this way. Once the magnesium alloy sheet, 1/16 or 3/32 in. thick, has been rolled, the edges are joined on a semi-automatic inert-arc welding machine. The alloy tube is then worked hot on spinning lathe to form model shell. Completed sections of shell are assembled to check for dimensional accuracy. Close tolerances are required because even slight errors lessen value of research information obtained during flight. Tail fins are of hollow cast magnesium, welded to the magnesium shell.

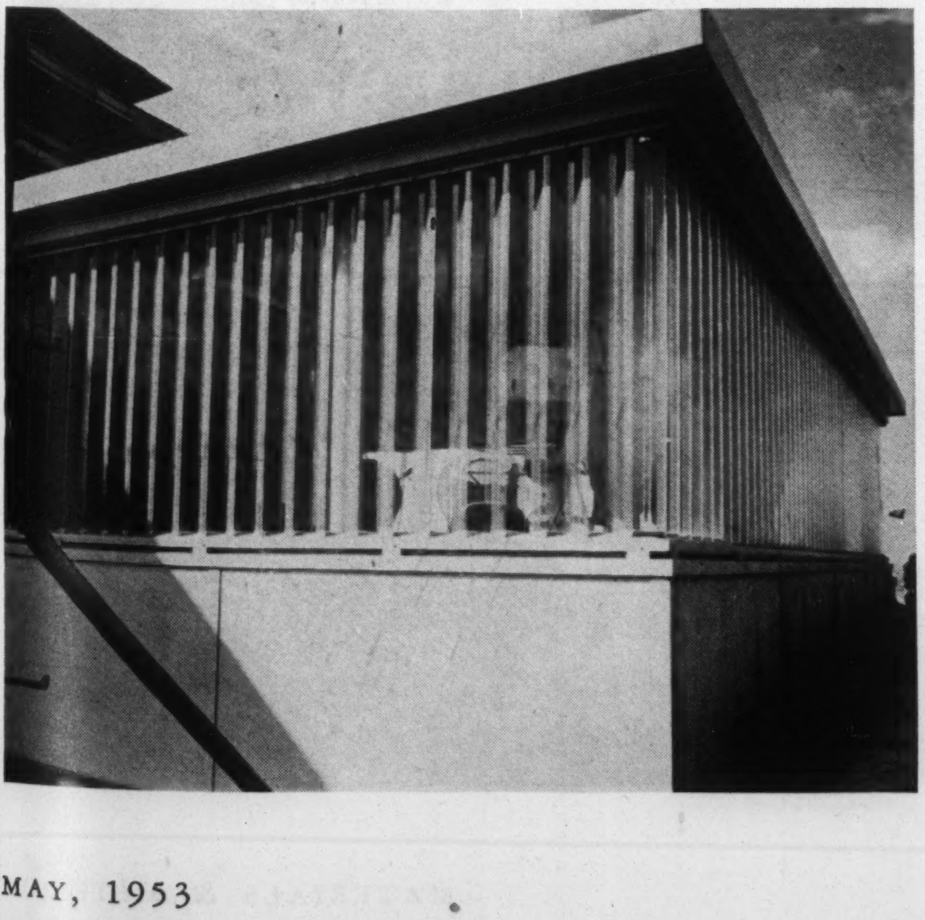






NICKEL-ALLOYED BRONZE NOSEPIECE In the development of their Dynoptic Laboratory Microscopes, Bausch & Lomb engineers sought a long-wearing metal out of which they could make the revolving, ball-bearing microscope nosepiece, which is subjected to considerable use and consequent wear in focusing on various objectives. A nickel-aluminum bronze alloy developed by Aurora Metal Co., and known as Aur-O-Met No. 56, was selected. A series of tests proved it superior in wear resistance to other nonferrous alloys tested. The fact that it could be cast close to finished dimensions by Aurora's Vacuum Die Process was an added advantage, since machining is reduced to a minimum.

The exceptional work hardening characteristics of Aur-O-Met No. 56 alloy promote long wear and high fatigue values. A microscope nosepiece is judged largely on the accuracy and repeatability with which it indexes from objective to objective. Performance tests made by Bausch & Lomb on the nosepiece shows a minimum service life of 45,000 cycles, and due to the nonbrinelling and work-hardening characteristics of the alloy, the part showed little or no wear. Other valuable contributions of this nickel aluminum bronze alloy to the success of the microscope are its excellent corrosion resistance and the fact that it provides a hard base metal for chromium plating.



ACRYLIC TV STATION HOUSING Communications engineers are housing antennas of radio and television relay stations and radar installations behind transparent protective walls of Plexiglas polymethyl methacrylate. A typical installation is a television relay station located on the roof of a tall building in Philadelphia. Acrylic glazing was installed to protect personnel and equipment from weather and wind. Transparency was required to permit sighting of the broadcast point and proper directioning of the parabolic reflectors. The problem was to gain this protection and transparency without distorting the wave forms and with maximum transmission efficiency.

Three sides were glazed with corrugated Plexiglas panels 6 ft high. Sheets used were limited to a maximum thickness of 1/8 in. By forming the sheets to a V-rib section with 8-in. frequency and 3-in. amplitude, rigidity was obtained despite the thin glazing employed.

Materials at Work

GLASS-POLYESTER SWITCH INSULATION

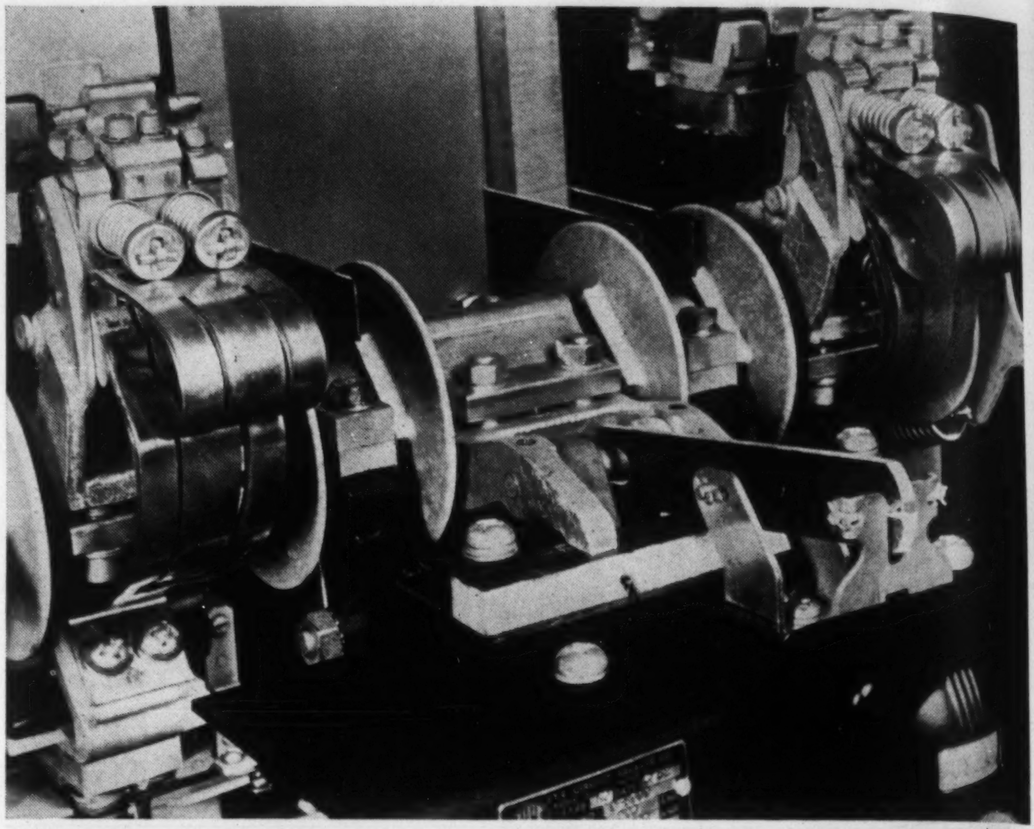
Glastic, a glass-reinforced alkyd polyester insulating plastic sheet stock, has replaced canvas phenolic materials in functional parts of switch gear equipment built by the I-T-E Circuit Breaker Co. This change is claimed to have achieved more dependable switch performance, while at the same time effecting an appreciable economy in material cost.

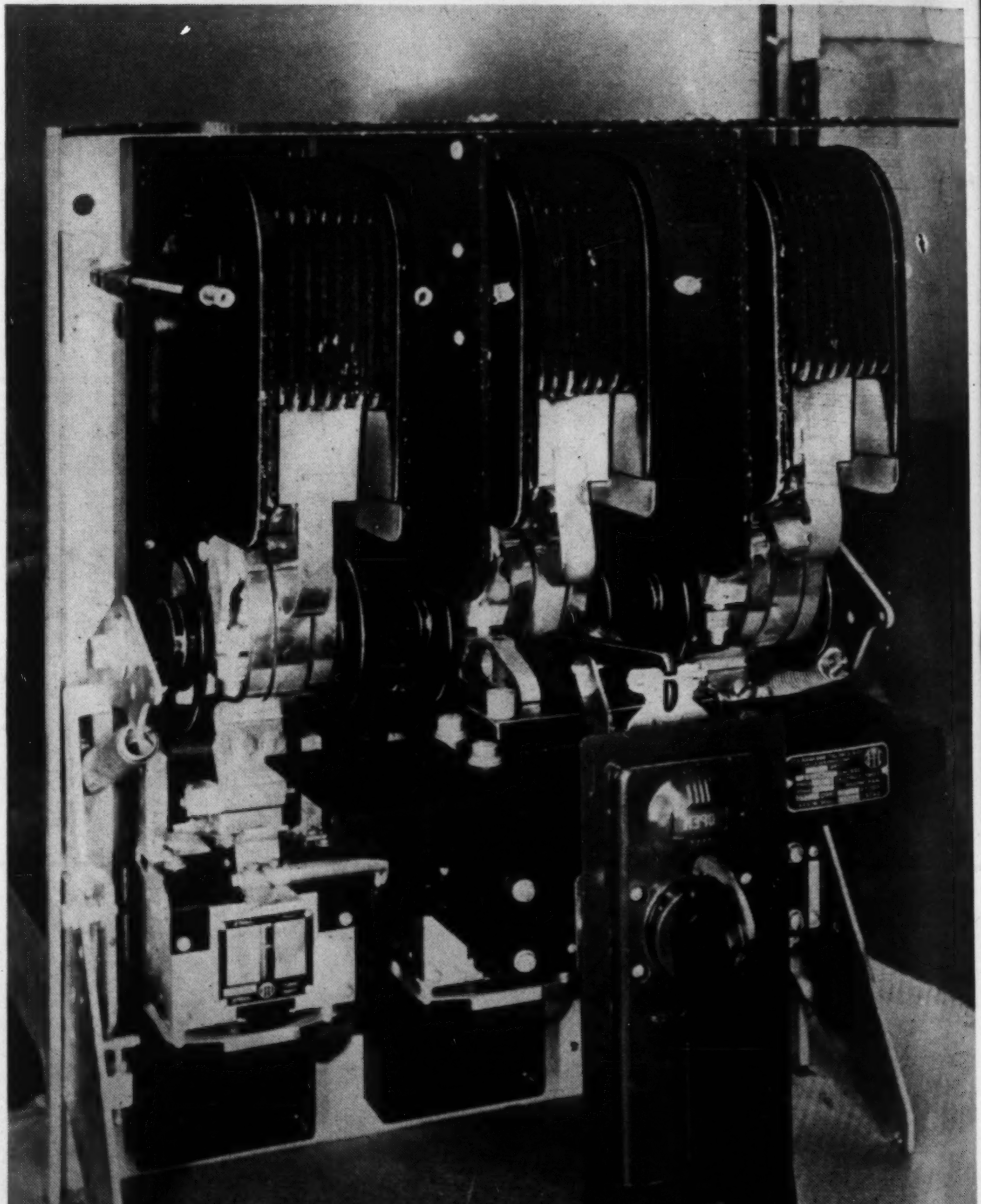
Glastic has been adopted for the main operating link because of high impact strength, high resistance to arc tracking, and excellent dimensional stability. This link transmits the actuating energy of the switch and insulates the closing mechanism from the contact arm. It must have adequate dielectric strength and withstand the shock during the snap action of opening and closing. Deterioration or breakdown cannot be tolerated even after long periods of heavy operating duty. The Glastic laminate chosen surpasses the canvas phenolic laminate formerly used in impact and flexural strength, resistance to arc tracking, moisture resistance, and dimensional stability. These improved properties were obtained simultaneously with direct material cost savings.

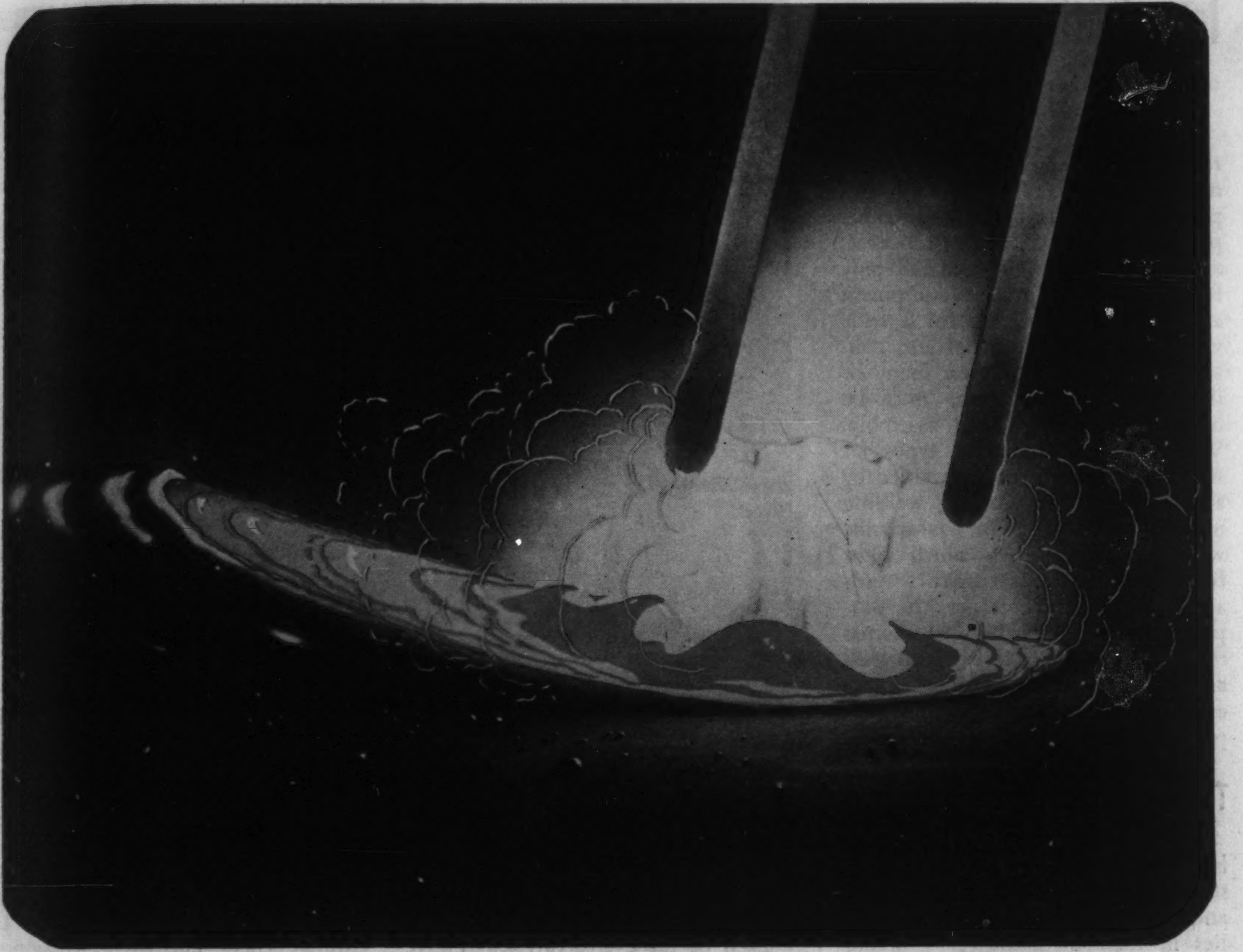
It is also claimed that the operating link pin life was extended by the new material. While phenolic tends to gradually wear the steel operating link pin, tests by the user show that the surface of Glastic exposed to the rotating friction of the pin develops a burnished condition which tends to reduce such wear.

A second application was the stop block, which absorbs the impact from travel during the opening of the spring loaded contact arm. It acts as a stop and supports the arm in the open position. The size of this block could be reduced by approximately one-half when Glastic was substituted for a phenolic laminate.

In a third application, the indicator switch lever, which acts as a linkage to an auxiliary switch and also serves to actuate the indicator, the cotton phenolic was replaced because Glastic has more favorable punching qualities.







Welding the Stainless Steels

by Helmut Thielsch

MATERIALS & METHODS MANUAL No. 94

This is another in a series of comprehensive articles on engineering materials and their processing. Each is complete in itself. These special sections provide the reader with useful data on characteristics of materials or fabricated parts and on their processing and applications.

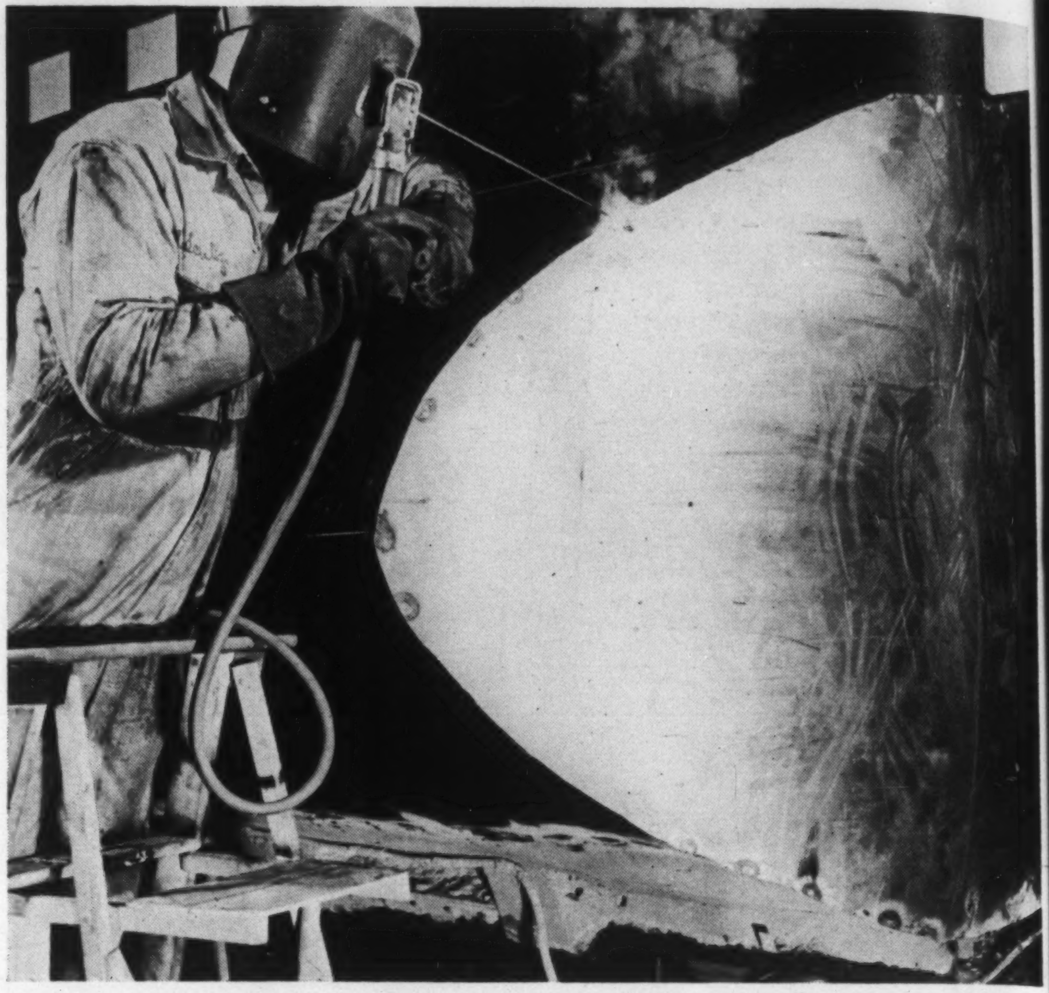
MAY 1953

Because the stainless steels are so widely used in welded fabrication, it is important to know how to weld them. While most commercial types are readily welded by most of the major methods, successful welding requires a knowledge of the welding characteristics peculiar to each of them. This Manual, therefore, provides information on the following subjects:

- ***Electrodes for Stainless Steels***
- ***Welding the Austenitic Grades***
- ***Welding the Martensitic Grades***
- ***Welding the Ferritic Grades***
- ***Procedures, Joint Designs and Preparation***

Introduction

Stainless steels, because of their resistance to many corrosive environments at room and at elevated temperatures and their many desirable physical and mechanical properties, are being increasingly used not only for all types of process equipment and machinery, but also for a wide variety of other industrial and consumer products. In a great many of these applications welding must be used for fabrication and assembly. While most commercial types of stainless steels are readily welded by almost all of the major welding methods, each of them has specific welding characteristics which must be understood if successful welds are to be made. Therefore, the purpose of this Manual is to discuss these welding characteristics, as well as the filler metals, welding processes and techniques commonly applied to stainless steels.



Shielded metal-arc welding of stainless steel milk truck.

The Commercial Stainless Steels

One of the primary differences between the two main groups of stainless steels—the chromium grades and the chromium-nickel grades—lies in their metallurgical structure and, because of this, an understanding of the basic structure characteristics of the commercial stainless steels is highly important to the solution of many welding problems and the correct selection of filler metals, processes and techniques. The three major metallurgical structures which characterize the stainless steels are austenite, ferrite and martensite. The chromium stainless steels, which contain from about 11 to 30% chromium, usually have either a primarily martensitic or ferritic structure. The chromium-nickel stainless steels, which contain between about 18 and 35% chromium and between about 6 and 36% nickel, are essentially austenitic.

Each of these structures will give a stainless steel certain characteristic properties, which may vary widely, and which will make the steel suitable or unsuitable for particular service or welding and other fabricating conditions. Ordinarily, the austenitic structure is strong, ductile, tough and nonmagnetic, the martensitic structure is hard, brittle and magnetic, and the ferritic structure is soft, ductile and magnetic. Another important difference is that the primarily austenitic chromium-nickel stainless steels have a high thermal expansion, about 60% greater than that of mild steel, whereas the martensitic and ferritic chromium stainless steels have a coefficient of expansion about 10% less than that of mild steel. The higher coefficient of expansion of the austenitic stainless steels may be responsible for serious cracking, distortion, and other undesirable features in welded joints. Moreover, the austenitic, martensitic and ferritic stainless steels have a low heat conductivity, about 1/3 to 1/2 that of mild steel. Since this will result in slower cooling of the stainless steel weld joint, undesirable features may be caused, which sometimes can be prevented by special cooling operations or heat treatments.

The steels in the chromium-nickel stainless steel group primarily have an austenitic structure. Since this austenitic structure does not essentially change at elevated temperatures, these steels cannot be hardened by heat treatments. A small amount of ferrite (up to 15%) may be present in the metallurgical structure of some of these primarily austenitic grades. The amount of ferrite largely depends upon the alloy balance, particularly the chromium-nickel ratio. The higher the nickel content, the smaller is the amount of residual ferrite. The presence of this small amount of ferrite may con-

About the Author. Helmut Thielsch, until recently, was Technical Assistant in the Welding Research Council. While there he prepared a comprehensive report on the welding of stainless steels. Thus, he brings to this subject a wide background of experience. This article is an outgrowth of his work with the WRC and of an educational lecture he presented before the New York Section of the American Welding Society. Mr. Thielsch is now Director of Applied Welding Engineering at Eutectic Welding Alloys Corp.

siderably reduce the hot formability and the elevated temperature creep strength of the steel. On the other hand, in weld deposits the presence of this ferrite phase is often desirable since it reduces the cracking susceptibility of the weld metal.

The chromium stainless steels (also called the *straight* chromium stainless steels) are generally separated into two further sub-classifications: (1) the martensitic stainless steels, and (2) the ferritic stainless steels.

The *martensitic or hardenable stainless steels* usually contain up to about 14% chromium. Although these grades may be made ferritic by heat treatments between 1200 and 1400 F, they are primarily martensitic when cooled in air or when quenched into a liquid medium from temperatures above the critical range (above about 1500 F). Thus, these steels may be hardened and tempered as the hardenable carbon and alloy steels.

The *ferritic stainless steels* usually contain between 18 and 30% chromium. These steels show no significant transformation on heating or cooling, remain essentially ferritic, and thus, can be hardened only by cold working.

Between 14 and 18% chromium, the separation between the martensitic and ferritic stainless classifications is approximate and depends upon the composition of the particular stainless grade—primarily the carbon content. Thus, a higher carbon content pushes the steel towards the hard martensitic structures, as occurs in the cutlery types. With a low carbon content they would be primarily ferritic. The addition of aluminum also will make the steel essentially ferritic at a relatively low chromium content, as in Type 405.

Whereas increases in the chromium content of the ferritic stainless steels improve their resistance to corrosion and to oxidation at elevated temperatures, their mechanical properties at room temperature are generally reduced. Above a chromium content of about 18% the low carbon fully ferritic chromium stainless steels become rather notch sensitive at room temperature.

Although at one time or another a great many different types of stainless steels have been produced commercially or experimentally, only the major commercial types and their welding characteristics are discussed here. In this country the more common wrought stainless steel grades are produced under standard type designations of the American Iron and Steel Institute (see Table 3). The few additional stainless steel alloys which are produced in the form of wrought products usually contain special alloying additions such as tungsten or copper to make the steel suitable for particularly severe corrosion or heat resisting applications.

The common cast stainless steels, which are produced according to designations by the Alloy Casting Institute, are listed in Table 4.

Electrodes for Welding Stainless Steels

Although stainless steel electrodes and welding rods are commercially available for any of the major welding processes, specifications have been written so far only for the more important covered metal-arc welding. electrodes. The American Welding Society and the American Society for Testing Materials have set up ten standard classes of electrodes for stainless steels in the specification "Corrosion Resisting Chromium and Chromium-Nickel Steel Welding Electrodes" (ASTM Designation A298-48T; AWS Designation A5.4-48T). The electrodes are classified on the basis of chemical analysis of the weld metal as specified below.

Table 1—AWS-ASTM Chemical Requirements for All-Weld-Metal Deposits from Covered Stainless Steel Electrodes

Electrode Designation	Chemical Composition, %							
	C, Max*	Mn, Max	Si, Max	P, Max	S, Max	Cr, Min	Ni	Others
E308	0.08	2.50	0.75	0.030	0.030	19.0	9.0 min	—
E309	0.15	2.50	0.75	0.030	0.030	22.0	12.0 min	—
E310	0.20	2.50	0.75	0.030	0.030	25.0	20.0 min	—
E316	0.08	2.50	0.75	0.030	0.030	17.0	11.0 min	Mo, 1.75–2.50
E317	0.08	2.50	0.75	0.030	0.030	18.0	12.0 min	Mo, 3.00–4.00
E330	0.25	2.50	0.75	0.030	0.030	14.0	33.0 min	—
E347	0.08	2.50	0.80	0.030	0.030	18.0	9.0 min	Cb, 10 x C, 1.20 max
E410	0.12	0.60	0.75	0.030	0.030	11.0	0.60 max	—
E430	0.10	0.75	0.75	0.030	0.030	15.0	0.60 max	—

** Carbon shall be analyzed to the nearest 0.01%.*

Table 2—Characteristics of Commercial Stainless Steel Shielded Metal-Arc Welding Electrodes

Stainless Steel Electrodes	Trade Designation[1]	Popular Designation[3]	Chemical Composition,[2] % C	Cr	Ni	Other Elements	Current	Coating Type	Color	Applications and Notes
AUSTENITIC	307	19-9 Mn	0.10 max	19.0 min	0.9 min	Mn 4.00	d.c.	Lime	Green	For hardenable steels, such as armorplate
	E 308	18-8 or 19-9	0.08 max	19.0 min	9.0 min	—	d.c. a.c.-d.c.	Lime Titania	Green Brown	For Types 301, 302, 302B, 303, 304, 305 and 308. Also used to provide a protective overlay on iron alloy or steel surfaces
	308 L	18-8 L	0.03 max	18.0-20.5	9.0-10.5	—	d.c.	Lime-titania	White	For Types 304L stainless steels
	E 309	25-12	0.15 max	22.0 min	12.0 min	—	d.c. a.c.-d.c.	Lime Titania	Green Brown	For Type 309 stainless steels, stainless clad steels and hardenable steels where postheat treatments are not possible
	309 Cb	25-12 Cb	0.10 max	22.0 min	12.0 min	Cb 10 x C min, 1.20 max	d.c. a.c.-d.c.	Lime Titania	Green Brown	For Type 347 stainless clad steels
	E 310	25-20	0.20 max	25.0 min	20.0 min	—	d.c. a.c.-d.c.	Lime Titania	Green Brown	For Type 310 stainless steels, stainless clad steels and hardenable steels where postheat treatments are not possible. To minimize crack sensitivity a min. carbon content of 0.09% in weld metal is desirable.
	310 Cb	25-20 Cb	0.12 Max	25.0 min	20.0 min	Cb 10 x C min, 1.20 max	d.c.	Lime	Green	For stabilized Type 310 stain-steels where extreme resistance to carbide precipitation is required and for Type 347 stainless clad steels
	310 Mo	25-20 Mo	0.15 max	25.0 min	20.0 min	Mo 2.00-2.50	d.c.	Lime	Green	For Type 310Mo stainless steels and for elevated temperature application where the added strength provided by Mo is desirable. To minimize crack sensitivity a min. carbon content of 0.09% in weld metal is desirable and Type 316 stainless clad steels.
	E 316	18-12 Mo	0.08 max	17.0 min	11.0 min	Mo 1.75-2.50	d.c. a.c.-d.c.	Lime Titania	Green Brown	For Type 316 stainless steels
	316 L	18-8 Mo L	0.03 max	17.0-19.0	12.0-14.0	Mo 1.75-2.50	d.c.	Lime-titania	White	For Type 316L stainless steels
	316 Cb	18-12 Mo Cb	0.08 max	18.0 min	10.0 min	Mo 1.75-2.50; Cb 10 x C min, 1.20 max	d.c. a.c.-d.c.	Lime Titania	Green Brown	For Type 316Cb stainless steels and high alloy steels used at high temperatures where intergranular carbide precipitation is to be prevented
	E 317	19-14 Mo	0.03 max	18.0 min	12.0 min	Mo 3.00-4.00	d.c. a.c.-d.c.	Lime Titania	Green Brown	For Type 317 stainless steels
	329	25-3 Mo	0.20 max	23.0-28.0	2.5-5.0	Mo 1.00-2.00	d.c.	Lime	Green	For Type 329 stainless steels
	E 330	15-35	0.25 max	14.0 min	33.0 min	—	d.c. a.c.-d.c.	Lime Titania	Green Brown	For Type 330 stainless steels and 15Cr-35Ni (Type HT) castings where welds require heat resistance up to 1900 F. To minimize crack sensitivity, a min. carbon content of 0.18% in weld metal is desirable.

Table 2—Characteristics of Commercial Stainless Steel Shielded Metal-Arc Welding Electrodes—(Continued)

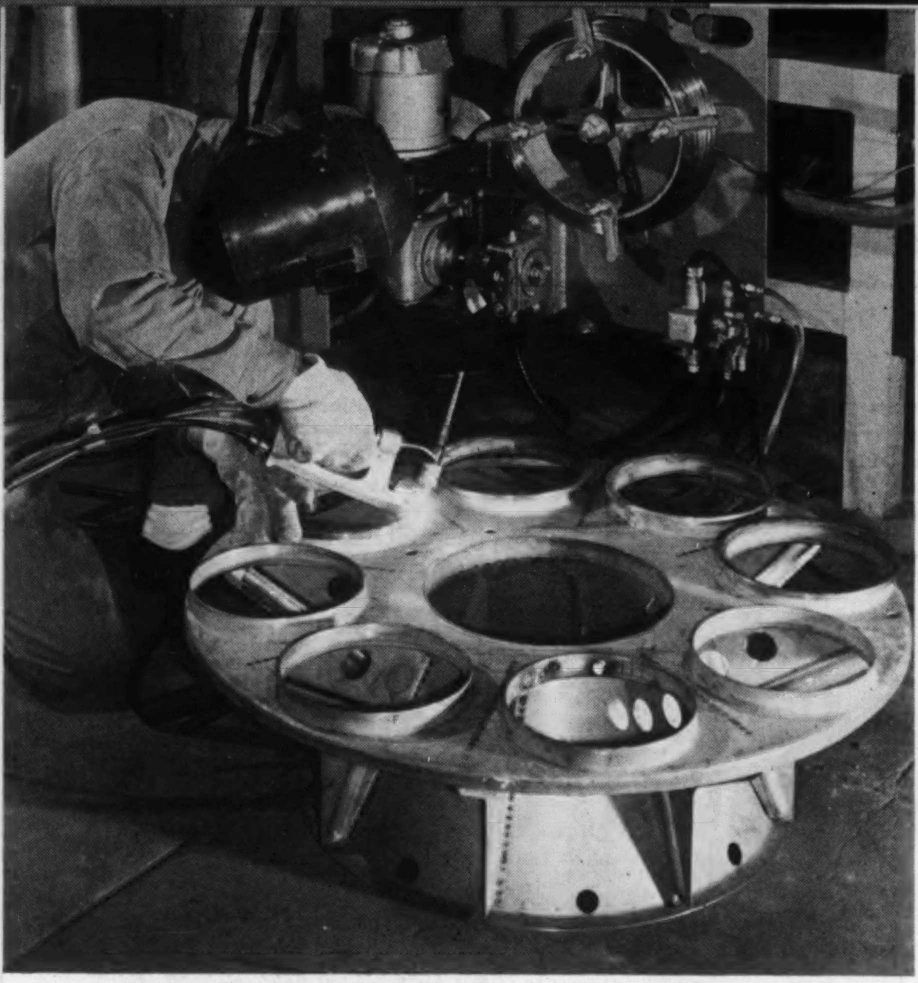
Stainless Steel Electrodes	Trade Designation[1]	Popular Designation[3]	Chemical Composition,[2] %			Other Elements	Current	Coating Type	Color	Applications and Notes
			C	Cr	Ni					
AUSTENITIC	E 347	19-9 Cb or 18-8 Cb	0.08 max	18.0 min	9.0 min	Cb 10 x C min, 12.0 max, Si 0.80 max	d.c. a.c.-d.c.	Lime Titania	Green Brown	For Type 347 and 321 stainless steels where weldments may be exposed to service temperatures between 800 and 1500 F
	312	29-9	0.08-0.15	26.0-31.0	8.5-10.5	—	d.c.	Lime	Green	For hardenable low- and medium-alloy wrought and cast steels requiring weld metal of high yield strength and high ductility
	—	19-9 W Mo	0.07-0.13	18.0-21.0	8.0-9.5	W 1.25-1.75, Mo 0.35-0.65, Cb 0.75-1.20	d.c.	Lime	Green	For high-alloy steels, of similar composition, exhibiting high creep strength at elevated temperatures
	Stainless W	—	0.07	17.0	7.0	Cb 2.0	d.c.	Lime	Green	For welding of Stainless W
	No. 20	20-29 Mo Cu	0.07 max	19.0-21.0	28.0-30.0	Mo 2.0-3.0, Cu 3.5-4.5, Cb 0.75-1.1	d.c.	Lime	Green	For 20 Cr-29 Ni-3Mo-Cu stainless steels
Martensitic	E 410	12 Cr	0.10 max	11.0-13.0	0.50 max	—	d.c.	Lime	Green	For Types 403, 410 and 414. Preheat and postheat treatments are recommended. (See Table 5).
FERRITIC	E 430	16 Cr	0.10 max	15.5-17.0	0.50 max	—	d.c.	Lime	Green	For Types 405, 416, 438, 440 and 441. This grade is less air hardening than Type 410. Ductility is considerably improved by heating to temperatures above 200 to 300 F. The alloy is also used for facing valve seats. Preheat and postheat treatments are recommended. (See Table 6).
	442	18 Cr	0.10 max	17.0-20.0	0.50 max	—	d.c.	Lime	Green	For Type 442 stainless steel. Preheat and postheat treatments are recommended. (See Table 6).
	446	28 Cr	0.10 max	25.0-29.0	0.50 max	N_2 0.25 max	d.c.	Lime	Green	For Types 442 and 446 stainless steels. Preheat and postheat treatments are generally recommended. (See Table 6).

[1] *Prefix E signifies standard AWS–ASTM Designation AWS A 5.4–48T, ASTM A298–48T.*
[2] *Unless otherwise specified, Mn is 2.5% max, Si is 0.75% max, and P and S are 0.030%max.*
[3] *The 18–12, 19–9, 19–14 grades are written by many manufactures as 18–8.*

Certain physical tests may be required for the purpose of classification, at the place of manufacture when and as prescribed by the electrode manufacturer. Tests may also be required by the purchaser (at his expense) as a basis for acceptance of the electrodes. The tests may be either all-weld-metal tension tests or fillet-weld tests. The latter, which is less expensive, is usually sufficient to determine acceptability. In addition, special supplementary tests may also be required to determine specific properties, such as corrosion resistance, scaling resistance, or strength at elevated temperatures.

Besides the electrodes produced to AWS-ASTM specification, and designated by the letter E which precedes the AISI type number, various additional electrode types are commonly produced by most of the major electrode manufacturers and are widely used. A summary of the welding characteristics of the commercially available stainless steel covered electrodes is given in Table 2.

Corresponding welding rods and wires for the other welding processes are also commercially available. For these, specifications are now being written.



Forged rings are welded to after-frame assembly for J-47 jet engine by inert-gas-shielded tungsten arc method.

SION
WILLIAMS INC

Spot welding Types 302 stainless steel in manufacture of Newman-Schmidt processing tank for color film.

Welding Characteristics

Certain alloying elements are not readily transferred from the electrode or welding rod to the weld metal pool. Instead, they may end up in the slag as oxides or other constituents, or may be lost with the gases as metallic vapor. The amount that is lost depends upon the welding process, the welding procedure, the electrode diameter and the type of electrode coating or gas shielding. Titanium, for example, is one of the alloying elements which is most readily oxidized. Since an oxidizing atmosphere is present in metal-arc welding with covered electrodes, most of the titanium would not be transferred to the weld metal pool but would be lost by oxidation of the titanium. Thus, titanium bearing (Type 321) electrodes are unsuitable for the metal arc welding process and, consequently, are not produced commercially. Where stabilization is necessary, the columbium bearing (Type 347) covered metal-arc welding electrodes are recommended. Similar considerations hold true for submerged-arc welding. On the other hand, in the inert-gas shielded arc welding processes the electrode, the welding rod and the weld metal are protected from the atmosphere so that almost all of the titanium is transferred into the weld metal. Consequently, titanium bearing (Type 321) filler metals are available commercially for the inert-gas shielded-arc welding processes. In metal-arc welding, a long arc also increases losses of certain elements through oxidation. Thus, a steady short arc is preferred.

Since the electrode and welding rod manufacturer knows from tests and experience what alloy losses can be expected from the various welding processes, procedures and filler metals, he will add an additional amount of alloying elements to the electrode covering or the welding rod which make up for the average expected losses. The user, therefore, is purchasing a weld deposit and, for this reason, the chemical and physical specifications pertain only to the weld metal.

Electrode Covering

The cellulose type covering, popular on most of the mild and low alloy steel electrodes, is not used on stainless steel electrodes because

Inert-gas-shielded metal arc welding of stainless steel tubing for chemical processing industry.

of the tendency of the weld metal to absorb carbon from these coverings. Instead, mineral type coverings are generally applied. Two major classifications are produced by most manufacturers. These are the lime and the titania type coverings. Although each electrode manufacturer varies the actual percentages of the mineral compounds used and the fabrication process for covering the electrode, the major difference between the coverings depends upon the amount of titanium-carrying compounds present in the coating.

In the lime type coverings, the titanium compounds amount to less than 8%. Because the slag which is formed is the least fluid and solidifies rapidly, these electrodes are preferred for welding in the vertical and overhead positions.

The titania types, containing over 20% titanium compounds, are more oxidizing than the lime types and give a smoother, softer welding arc. Sputtering is minimized and a greater arc stability is obtained. The more fluid slag moves rapidly to the back half of the puddle, has very little tendency to interfere with the welding operation, and makes greater welding speeds possible. The slag, when cooled, is hard and glassy.

The titania type electrodes can be used with either a.c. or d.c. reverse polarity, whereas the lime type electrodes are suitable for only d.c. welding.

Welding the Austenitic Stainless Steels

The common commercial wrought and cast chromium-nickel stainless steels and their welding characteristics are given in Tables 3 and 4, respectively. These grades are readily weldable by any of the major welding processes.

Problem of Carbide Precipitation

When the common austenitic chromium-nickel stainless steels as Types 302, 304, 308, 309, 310, 316 and 317 are exposed during fabrication or use, in the temperature range between 900 and 1500 F, the carbon tends to diffuse to the grain boundaries and combine with chromium to form chromium-carbide particles. This process is known as *intergranular carbide precipitation* and a stainless steel in which it has occurred is usually described as *sensitized* by the exposure in the critical sensitizing temperature range. The precipitation of these chromium-carbide particles at the grain boundaries is generally believed to reduce by several per cent the "free" or uncombined chromium near the grain boundaries which is available for corrosion resistance and, in this manner, lowers the resistance of the stainless steel to certain liquid, usually aqueous, corrosive solutions.

Because the corrosive attack occurs at the chromium impoverished areas at the grain boundaries, it is known as *intergranular corrosion.* The actual severity of the effect of the intergranular chromium carbide precipitation primarily depends upon the carbon content of the steel, the temperature, and the length of time it is held in the critical temperature range. The rate of precipitation occurs most rapidly at about 1200 F Thus, the Type 301 and 302 stainless steels which ordinarily contain between 0.08 and 0.20% carbon are more susceptible to intergranular carbide precipitation than Types 304 and 308, which contain less than 0.08% carbon. The rate of intergranular carbide precipitation is slightly retarded by a higher chromium and/or molybdenum content as in the 25Cr-12Ni (Type 309) or 25Cr-20Ni (Type 310) or in the 18Cr-8Ni-Mo (Type 316) grades.

Intergranular corrosion of these grades may be prevented by a suitable annealing heat treatment between about 1850 and 2050 F and quenching, which follows the final fabricating operation. Although stainless steel sheets and plates are usually purchased from the steel producer in the annealed condition,

Table 3—Welding Recommendations for Common Austenitic Stainless Steels

AISI Designation	Popular Designation[2]	Recommended Electrode[1]
301	17–7	E 308
302	18–8	E 308
302 B	18–8 Si	E 308
303	18–8 FM	E 308
304	19–9	E 308
304L	19–9 (extra-low-carbon)	308L or E347
305	18–10	E 308
308	20–10	E 308
309	25–12	E 309
309 S	25–12 low C	E 309
309 Cb	25–12 Cb	309 Cb
310	25–20	E 310[3]
310 S	25–10 low C	E 310
310 Cb	25–10 Cb	310 Cb
310 Mo	25–20 Mo	310 Mo
314	25–20 Si	E 310
316	18–12 Mo	E 316
TS 316	18–12 Mo	E 316
316L	18–12 Mo (extra-low-carbon)	316L or 318
317	19–13 Mo	E 317
318	18–12 Mo Cb	318
321	18–8 Ti	E 347
347	18–8 Cb	E 347[4]
TS 347	18–8 Cb	E 347[4]
TS 347 A	18–8 Cb-Ta	E 347[4]

[1] *Characteristics of the commercial stainless steel welding electrodes are given in Table 2.*

[2] *The 17–7, 18–10, 19–9, 19–12 designation are also often described as 18–8.*

[3] *Type E310 electrodes with high carbon content (0.18–0.25% C) may be necessary when welding heavy sections under severe restraint.*

[4] *Preheating may be necessary when welding heavy sections under severe restraint.*

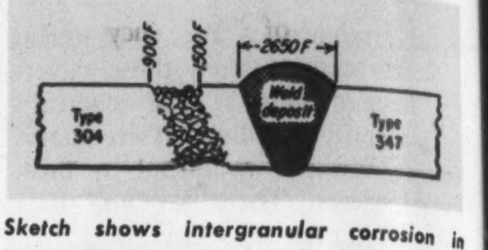
such a high-temperature heat treatment and severe quench are often detrimental to the fabricated structure.

Fortunately, there are several other ways to prevent intergranular precipitation of chromium carbides. One method is to add columbium, tantalum or titanium to the steel—a procedure which is known as *stabilization.* These stabilizing elements form carbides more readily than chromium and, in this manner, they prevent the undesirable chromium impoverishment at the grain boundaries which results from the intergranular precipitation of chromium carbides.

Finally, by limiting the carbon content to 0.03% max, the time for carbide precipitation in these so-called extra-low-carbon steels can be lengthened so that all normal welding and stress relieving operations may be carried out without causing harmful effects. Some slight chromium carbide precipitation may nevertheless take place in the grains upon very prolonged exposure at the sensitizing temperatures (900 to 1500 F).

Intergranular carbide precipitation is important in welding since there is inevitably a zone near the weld that has been exposed in the sensitizing temperature range between 900 and 1500 F. The effect of welding upon intergranular carbide precipitation and corrosion are illustrated schematically in the accompanying figure for a weld between Type 304 and Type 347 sections in the "as welded" condition. Whereas, intergranular corrosion occurred in the unstabilized Type 304 grade, the stabilized Type 347 grade was not attacked.

Since welding exposes the stainless steel for only a relatively brief period in the sensitizing temperature range, the amount of intergranular carbide precipitation after welding is less severe than it would be after a prolonged service exposure in the same temperature range. Unless the stainless steel is subsequently exposed to highly corrosive solutions, the presence of a slight amount of precipitated carbides usually does not affect the life of the equipment. In fact, in the mildly corrosive conditions to which dairy machinery, kitchen and cafeteria equipment, and architectural decorative work are generally exposed, welded structures made even of Types 301 and 302 (0.20% max carbon) may give entirely satisfactory service even though the welding operation is likely to have produced some intergranular carbide precipitation.



Sketch shows intergranular corrosion in heat affected zone of Type 304 stainless. Right side depicts the freedom from this condition in Type 347 in as-welded condition.

In many other mildly corrosive applications the 0.08% max carbon Types 304, 308, 309S and 310S and the 0.10% max carbon Type 316 and 317 may be completely satisfactory in the as-welded condition—although stress-relieving heat treatments between 900 and 1500 F may be detrimental. In these grades intergranular carbide precipitation in the heat affected zone becomes appreciable only when the cooling time through the 900 to 1500 F temperature range exceeds approximately 1 min. Thus, the thinner gages (below about 1/16 in.) can be readily welded without significant intergranular precipitation of carbides. When heavier gages of these nonstabilized grades are being welded and when the service environment demands the absence of intergranular chromium carbide precipitation in the steel, special precautions should be taken to allow the weldment to cool as rapidly as possible. This is generally accomplished by (1) use of small diameter electrodes, (2) low welding current, (3) deposition of the filler metal with a string bead technique (no weaving), (4) use of chill bars in the fixtures, and/or (5) following the welding operation by immediate application of an air blast or a water quench or spray.

When it is not possible to provide the necessary rapid cooling rates, or when the corrosive application is severe, the stabilized stainless steel grades may have to be used. In fact, in the past the columbium-bearing Types 347, 309Cb and 310Cb grades have often been specified even for applications which were not sufficiently severe to necessitate their use, yet the added resistance to intergranular corrosion provided a safety factor which was often comfortable to the designer, producer and user of such equipment. However, the present shortages of columbium have made these particular grades relatively unavailable, so that more economic use has to be made of the

Table 4—Welding Recommendations for the Common Commercial ACI Austenitic Stainless Castings

ACI Designation	Popular Designation	Recommended Electrode[1]
CE-30	25-10	312
CF-8	19-9	E 308
CF-20	19-9	E 308
CF-8M	19-10 Mo	E 316
CF-12M	19-10 Mo	E 316
CF-8C	19-10 Cb	E 347[3]
CF-16F	19-10 Mo FM	E 308
CF-16Fa	19-10 Mo FM	E 308
CG-12	22-12	E 309
CH-10	25-12	E 309
CH-20	25-12	E 309
CK-20	25-20	E 310
CN-7M Cu	—	20-29 MoCu
HC	28-4	329
HD	28-7	312
HE	28-10	312
HF	20-10	E 308
HH	27-12	E 309
HI	28-16	E 309
HK	25-20	E 310
HL	30-20	E 310[2]
HT	15-35	E 330[2]
HU	19-39	E 330[2]

[1] *Characteristics of the commercial stainless steel electrodes are given in Table 2.*

[2] *Where severe restraint (as in heavy sections) may cause cracking, the root bead should be made with 29 Cr-9Ni; or "partially ferritic" 25 Cr-12Ni electrodes, subsequent deposit may be made with the E 310 or E 330 electrodes recommended.*

[3] *Preheating may be necessary when welding heavy sections under severe restraint.*

other available grades.

In severely corrosive applications and in medium corrosive applications where the structures have to be stress relieved, the titanium stabilized Type 321 grade or the recently designated extra-low-carbon (0.03% max carbon) Types 304L and 316L are now being used with good success. With less than 0.03% carbon available in the extra-low-carbon grades, intergranular carbide precipitation is usually avoided. However, the extra-low-carbon stainless steel electrodes do not weld as satisfactorily as the standard or stabilized 18Cr-8Ni-Cb (E 347) electrodes which, therefore, are preferred whenever possible. The extra-low-carbon grades should not be used in structures that are exposed during service at temperatures above 800 F.

Equipment that is exposed to corrosive environments and also to continuous or intermittent service at temperatures above 800 F is generally made of the stabilized stainless grades. Moreover, electrodes from columbium stabilized grades are recommended for welding because titanium tends to burn off as oxide and to segregate during welding. An exception is the inert-gas welding processes where the gas shielding provided allows titanium recovery from the filler wires of 60 to 85%; however, even then the columbium bearing welding rods and electrodes are preferred.

Sigma Phase Formation

In addition to austenite, ferrite and carbide, another structure known as *sigma phase* may appear in many austenitic stainless steel alloys. Since this phase is highly brittle, it may, when present in sufficient quantities, seriously reduce the ductility and toughness of the steel.

Ordinarily sigma formation may occur in the susceptible grades upon exposure between approximately 1050 and 1700 F. Fortunately, in most of the commercial austenitic stainless steels considerable time, often months or years, is required at these temperatures before sufficient quantities of sigma, if it forms at all, have appeared to seriously affect the service life of the structure.

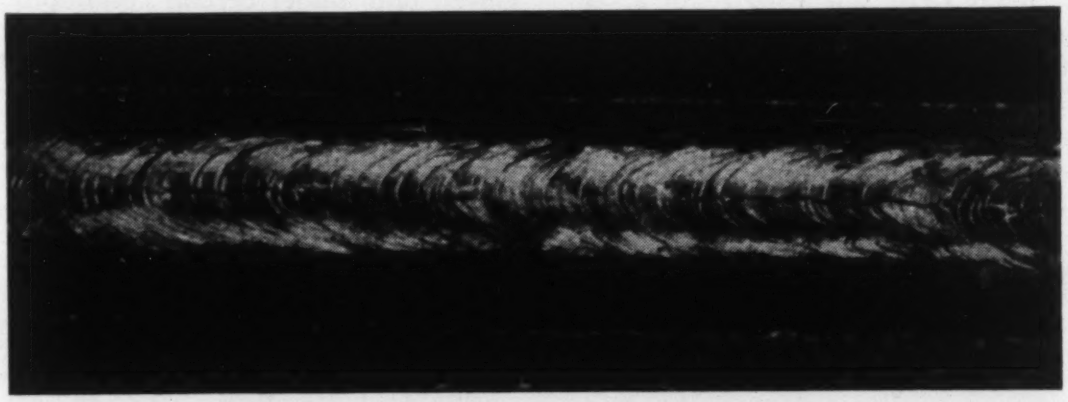
Sigma is rarely observed in "as deposited" welds. The only exception may be deposits of unusually high molybdenum and/or silicon content.

Although on exposure to temperature at which sigma may form the stainless steel weld metal may be more susceptible to sigma formation than wrought alloys of similar composition, the ordinary stress-relieving heat treatments are unlikely to cause formation of detrimental quantities of sigma. Thus, the problem of sigma formation is primarily of concern to the designer and user of high temperature equipment.

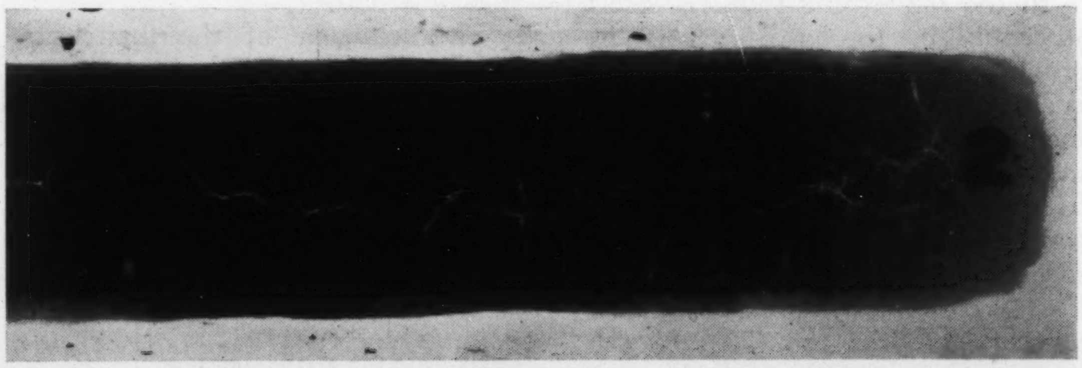
Hot Cracking of Weld Metal

Stainless steel weld metal, after solidifying at about 2650 F, is relatively weak in the dendritic grain boundaries until it has cooled down to temperatures below about 1400 F. When shrinkage and restraint induce stresses of serious magnitude, hot cracking may be the result. Two types of hot cracks are most common: (1) longitudinal bead or crater cracks are illustrated in the accompanying figure, and (2) fine and multi-directional cracks also known as "check" cracks are shown. Since the cracking tendency depends upon a variety of factors such as (1) metallurgical structure of the weld metal, (2) electrode (or welding) and base steel composition, (3) welding process, (4) welding technique and procedure, (5) electrode coating or welding flux, (6) weld geometry, (7) degree of restraint, etc., the major cause may not always be readily apparent. Because the composition of most commercial stainless steel electrodes and welding rods is rather carefully controlled by the manufacturer, hot cracking is more likely to be the result of unusual or unfavorable welding conditions. Thus, most hot cracking failures occur when heavy sections are welded under conditions of severe restraint, particularly in the root bead. Electrodes and welding rods which produce fully austenitic weld deposits (Types 309 and 310) usually are considered to be more susceptible to hot cracking than the lower nickel 18Cr-8 Ni or 29Cr-9Ni grades, if these produce weld deposits containing some ferrite.

When the conditions are favorable for cracking, the welding engineer has several means by which he can minimize the hot cracking tendency of the weld metal. For example, welding procedures and techniques which minimize the amount of heat introduced into the weld joint are usually beneficial, such as the use of small diameter electrodes, stringer beads, etc. When welding heavy sections of the 18Cr-8Ni type grades, electrodes should be used having a composition which would produce a weld deposit containing a small amount of ferrite in addition to the major constituent austenite. When the more highly alloyed Types 309 and 310 have to be welded under



Longitudinal or centerline crack in a 25 nickel-20% chromium weld deposit.



Radiograph illustrating check cracks in stainless steel weld deposit made by electric arc welding.

conditions favorable for hot cracking, as for example, severe restraint, the electrode manufacturers should be contacted for electrodes and welding rods manufactured to particularly close tolerances in their composition. These electrodes and filler metals are usually made less crack sensitive by careful control of some of the minor residual elements, such as carbon, silicon, copper and sulfur.

Preheat Treatments

The austenitic stainless steels should generally not be preheated prior to welding since such a treatment would decrease the rate of cooling of the weld and heat-affected zone, and would, therefore, increase the amount of carbide precipitation in the weldment. An exception to this is made by a number of manufacturers when heavy sections of Type 347 stainless steel are welded under severe restraint where cracking in the weld metal and in the heat-affected zone, which may occur at room temperature, may be prevented or minimized by a preheat treatment at temperatures as high as 1000 F.

Annealing

If intergranular chromium carbides have been formed, the carbon and chromium can be brought back into solution by heating the steels between 1850 and 2050 F for about ½ to 1 hr per in. of thickness but not less than 30 min. Temperatures in the upper part of the range should be used for the austenitic-stainless steels with a higher carbon content (above 0.10% C) and/or a higher chromium-nickel content (25 Cr-12Ni, 25Cr-20Ni, 15Cr-35Ni stainless grades). This so-called solution heat treatment should be followed by quenching in water or by a water spray. However, the supply and pressure of water should be sufficient to prevent the formation of a "steam blanket," which would retard the cooling rates. For sections less than ⅛ in. thick, water quenching is also recommended although when water quenching is impractical a forced air quench may be sufficient.

Stress Relieving

Stress relieving heat treatments are less effective in relieving residual stresses in stainless steels than they would be in carbon steels since, at elevated temperatures, the austenitic stainless steels have a relatively high yield point. Thus, stress relieving heat treatments in the temperature range from 1100 to 1250 F (normal for carbon steels) are less than 50% effective for stainless steels. However, stress relieving at 1600 F is generally believed to be about 90% effective. Because the detrimental effects produced by stress relieving may sometimes outweigh the advantages gained, the austenitic stainless steels should be stress relieved only under certain conditions.

In the 1952 ASME Boiler and Pressure Vessel Code (Section VIII, Unfired Pressure Vessels) mandatory thermal stress relief requirements have been omitted, since service experience is too limited to permit comparison between the relative safety of as-welded and stress relieved austenitic stainless steel weldments. However, there are many occasions where it would be unwise not to stress relieve. For example, welded joints in heavy sections of ¾-in. thickness or more generally should be stress relieved. Also, any vessel which is in service where stress corrosion might be encountered should be stress relieved.

With the exception of the extra-low-carbon and the stabilized grades, the stress relieving temperatures for the nonstabilized grades should be kept below 1000 F. Although stress relieving below 1000 F will be far from complete, it may be sufficient for the intended service. Where higher stress relieving temperatures are specified, the stabilized or extra-low-carbon grades should be used. Stress relieving at 1350 F for 1 hr per in. of thickness would represent the customary procedure. Where complete stress relieving is necessary, the temperatures should be between 1600 and 1800 F so that the use of stabilized grades is essential.

In stainless clad steels and in dissimilar metal joints, postheat treatments are also sometimes recommended, and then largely because of their possible beneficial effects on the lower plain carbon or alloy backing or base steel.

Welding the Martensitic Stainless Steels

The welding characteristics of the common commercial wrought martensitic stainless steels are given in Table 5.

In the martensitic stainless steels, susceptibility to hardening is increased as the chromium content is decreased and the carbon content is increased. Steels with high chromium and low carbon content tend to approach the characteristics of the ferritic stainless steels. Thus, in the absence of other alloying elements a 13% chromium stainless steel containing less than about 0.08% carbon is often considered to be only partially martensitic. In these so-called modified Type 410 alloys the maximum hardness obtained will usually be below Rockwell C 40. Alloys with more than 0.08% carbon would be considered to be essentially fully martensitic.

The tendency of the martensitic weld metal and the heat-affected zone to be hard and brittle is often minimized by suitable pre- and postheat treatments. The generally recommended procedure may vary somewhat with the particular degree of hardening of each grade of steel.

Fully Martensitic Grades

Without suitable heat treatments these steels generally exhibit poor welding characteristics and are susceptible to cracking in the martensitic weld deposit or in the heat-affected zone, particularly when heavy sections are being welded. Only in thin plates up to about ⅛ in. is Type 410 likely to exhibit good welding characteristics so that preheating would provide little improvement and may be omitted.

Cracking may be minimized by preheating these steels prior to welding at 600 and 800 F. With electrodes which are completely moisture-free, preheating temperatures as low as 300 F may be satisfactory. These temperatures should be maintained during the welding operation.

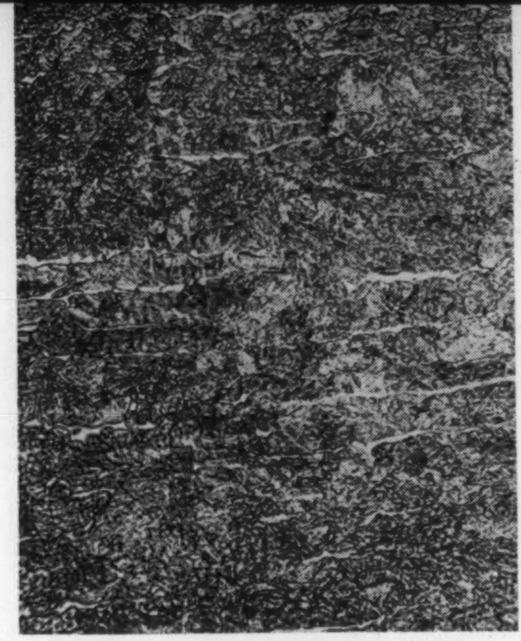
Moreover, a postheat treatment between 1300 and 1450 F should follow directly after welding without intermediate cooling of the section. The postheat treated sections should be cooled in air. Under these conditions very ductile weldments may be obtained.

Partially Martensitic Grades

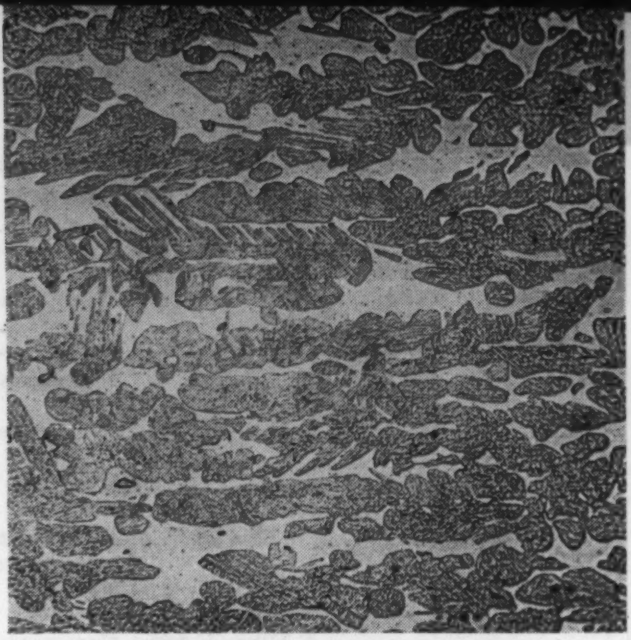
The presence of some ferrite in the otherwise martensitic structure decreases the overall hardenability of the steel. This reduces the cracking susceptibility. Nevertheless, cooling rates and interpass temperatures should be controlled. Preheat treatment between 300 and 500 F is generally advisable and should be followed by an immediate postheat treatment at 1300 to 1450 F. Only when welding sheet below about 3/16 in. may these preheat and postheat treatments be omitted.

Austenitic Chromium-Nickel Electrodes

Welding with these electrodes is usually preferred, particularly when a postheat treatment is not possible. Small diameter electrodes and low welding currents should be used to minimize heating of the base steel and to minimize penetration. For best results it is generally preferred practice to weld the Type 410 alloys with a 25Cr-20Ni or 25Cr-12Ni electrode and with suitable pre- and postheat treatments.



Example of fully martensitic structure of 0.12% carbon Type 410 stainless after air cooling from 1800 F. Hardness is Rockwell C 45. (Magnification 200X)



Example of partially martensitic structure of 0.06% larbon Type 410 stainless after air cooling from 1800 F. Hardness is Rockwell C 38. (Magnification 200X)

Martensitic Electrodes

Ordinarily, when commercial Type 410 electrodes are used to weld the Type 410 stainless steels, a preheating temperature at about 300 F is in most cases advisable. When low carbon (modified—0.08% max C) Type 410 grades are welded with Type 410 electrodes, this preheat treatment may not be required. However, post-heat treatments between 1300 and 1450 F should still be employed when good ductility and toughness are of primary concern.

Table 5—Welding Recommendations for the Common Commercial AISI Martensitic Stainless Steels

AISI Designation	Popular Designation	Recommended Electrode*	Preheat and Interpass Temperature, F	Postheat Treatment at 1300–1450 F for 1 Hr per In. of Thickness	Notes
403	12 Cr	E 410			
410	12 Cr	E 310 or E 309	300–500 F highly recommended where possible	Recommended but not necessary	When preheat treatments are not employed, use small diameter electrodes
		410	300–500 F	Highly recommended	
410 Mod.	12 Cr	E 310 or E 309	300–500 F highly recommended where possible	Recommended but not necessary	
		E 410	300–500 F	Highly recommended	On thinner gages postheat treatments may be omitted.
414	12 Cr–2 Ni	E 310 or E 309	400–600 F	Recommended	
		E 410	400–600 F	Highly recommended	
416	12 Cr–FM	E 430			Welding not recommended
420		E 310 or E 309	400–600 F	Recommended	
		E 410 or E 430	600–800 F	Highly recommended	
440–A	17 Cr				These steels are not recommended for welding. When welding or repair welding is necessary, pre- and postheat treatments must be employed.
440–B	17 Cr	E 410	600–800 F	Required	
440–C	17 Cr				

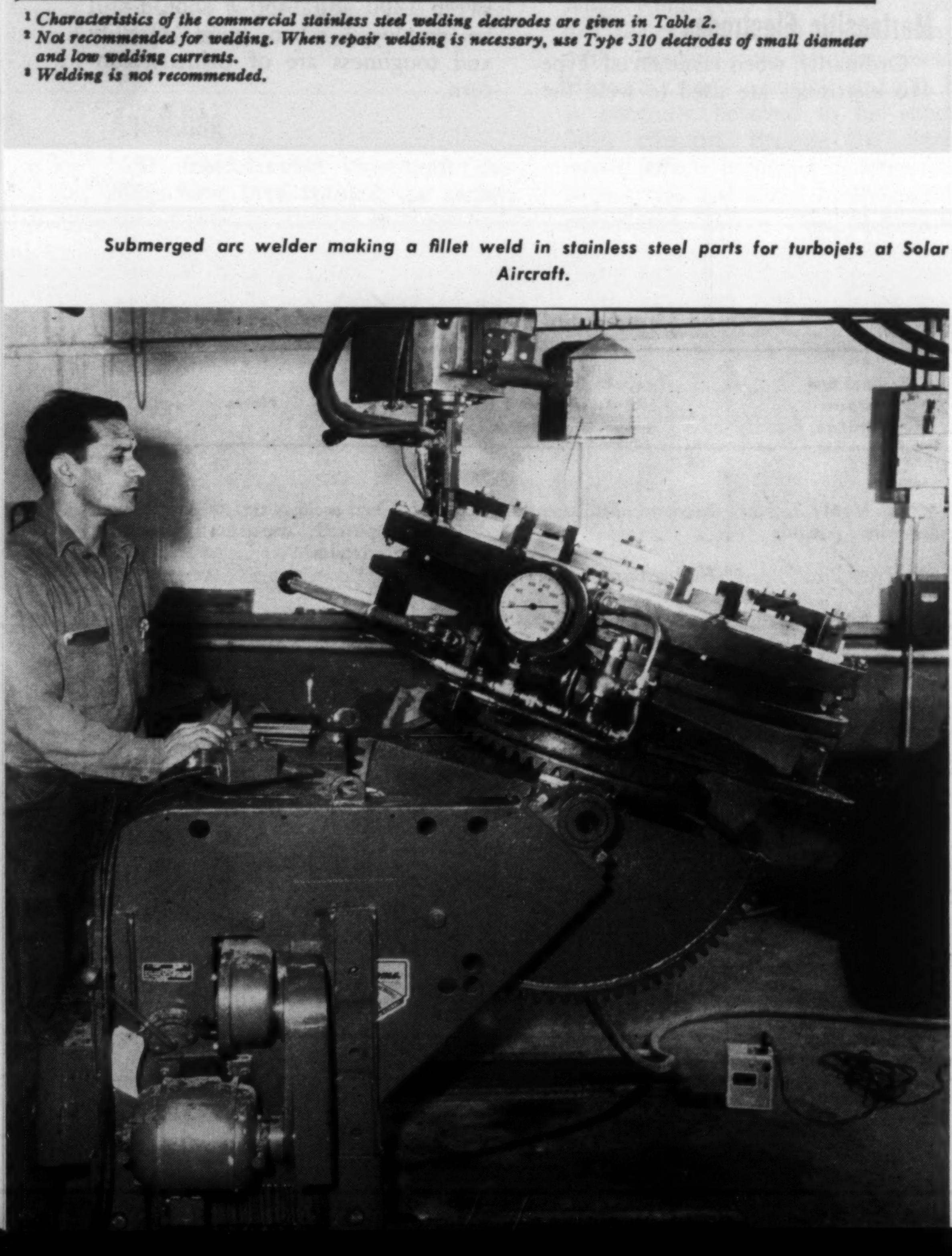
* *Characteristics of the commercial stainless steel welding electrodes are given in Table 2.*

Table 6—Welding Recommendations for the Common Commercial AISI Ferritic Stainless Steels

AISI Designation	Popular Designation	Recommended Electrode[1]	Preheat and Interpass Temperature	Postheat Treatment at 1300-1450 F for 1 Hr per In. of Thickness
405	12 Cr–Al	E 430	Not necessary	Essential
		E 310 or E 309	Not necessary	Recommended
406[2]	12 Cr–4 Al			
430	16 Cr	E 430	Not necessary, but usually recommended between 300-400 F	Essential
		E 310 or E 309	Not necessary	Recommended
430–F[3]	10 Cr–FM			
431	16 Cr–2 Ni	E 430	Not necessary, but usually recommended between 300-400 F	Essential
		E 310 or E 309	Not necessary	Recommended
442	18 Cr	442 or 446	Not necessary, but usually recommended between 300-400 F	Essential
		E 310 or E 309	Not necessary	Highly recommended
446	27 Cr	446	300-400 F	Essential
		E 310 or E 309	Not necessary	Highly recommended

[1] Characteristics of the commercial stainless steel welding electrodes are given in Table 2.
[2] Not recommended for welding. When repair welding is necessary, use Type 310 electrodes of small diameter and low welding currents.
[3] Welding is not recommended.

Submerged arc welder making a fillet weld in stainless steel parts for turbojets at Solar Aircraft.



Welding the Ferritic Stainless Steels

Welding recommendations for the common commercial wrought ferritic stainless steels are given in Table 6. Since the ferritic stainless steels are not subject to air hardening, they are less susceptible to cracking in the welded section than the martensitic stainless steels. However, these steels may be embrittled by ordinary welding procedures.

The chromium stainless steels, which become fully ferritic at temperatures above 2100 F, are generally susceptible to an embrittlement that is associated with solution of the carbides. This embrittlement is accompanied by severe grain growth. The effects of this embrittlement can usually be removed by annealing the steel for 1 hr between about 1300 and 1450 F even though the grain size remains coarse. Such a postheat treatment is particularly important in single-pass welds, where without this heat treatment, the ferritic weld metal as well as part of the heat-affected zone would be extremely brittle, and would readily crack on subsequent deformation or bending operations at room temperature.

When such postheat treatments are not possible, multi-pass welding with small diameter electrodes, low current and stringer beads should be used to minimize this embrittlement. In these deposits the subsequent weld beads will produce annealing effects in the earlier beads and, as such, reduce the brittleness in the weldment.

Austenitic Chromium-Nickel Electrodes

Austenitic 25Cr-20Ni or 25Cr-12Ni (Types 310 or 309) electrodes are generally preferred because satisfactory results are frequently obtained even without pre- and post-heat treatments.

Since the austenitic stainless steels have a coefficient of expansion about 50% greater than that of the ferritic stainless steels, austenitic electrodes should be used primarily in structures that are operated at room temperature or within a relatively narrow temperature range. Severe and frequent temperature variations may lead to thermal fatigue failure.

Although the austenitic weld deposit itself may not require a postheat treatment at intermediate temperatures, the heat-affected zone of the ferritic parent metal may become sufficiently embrittled to require such a heat treatment when single-bead deposits are made. Multi-bead deposits are usually sufficiently ductile to be used without preheat.

In corrosive applications, where it would be detrimental to have austenitic chromium-nickel weld metal adjacent to a ferritic stainless steel base which is exposed to the corrosive solution, it may sometimes be advisable to deposit 30% chromium filler metal on that side of the weldment which is exposed to the corrosive solution after the balance of the weld metal has been made with 25Cr-20Ni or 25Cr-12Ni electrodes.

Ferritic Welding Electrodes

Since Types 405, 430 and 431 generally contain an average of about 50 to 70% ferrite, the balance being martensite, some hardening may occur in these grades. Although in welding chromium stainless steels containing up to 23% chromium good joints can usually be obtained with electrodes having compositions similar to the parent metal, the 25Cr-12Ni (Type 309) austenitic stainless-steel electrodes or welding rods are still commonly used. When straight chromium stainless steel electrodes or welding rods are used, preheat treatments are preferred to reduce strains in the embrittled heat-affected zone. A postheat treatment at intermediate temperatures is essential if ductility is of importance, unless service at elevated temperatures above 1000 F is used to produce a similar effect.

Chromium stainless steels containing more than 23% chromium are preferably welded with 25Cr-20Ni or 25Cr-12Ni (Types 310 or 309) electrodes. This, however, may not always be possible since certain corrosive applications require that the high chromium stainless steel be welded with an electrode of similar composition. For example, pipes or vessels that are exposed at elevated temperatures to sulfur and sulfurous gases should not be welded with austenitic chromium nickel electrodes because the presence of nickel is undesirable.

Since weld metal brittleness in ferritic weld deposits increases with higher chromium content, preheat treatments between 300 and 400 F are always advisable in steels containing over 18% chromium.

Welding Procedure, Joint Designs and Joint Preparation

Most of the commercial stainless steel grades can be readily welded by any one of the common welding processes such as shielded metal-arc, submerged-arc, oxyacetylene, resistance, atomic-hydrogen, and inert-gas-arc welding. Although ordinary carbon-arc welding has been successfully used on thin stainless steel sheets, it has not found wide acceptance because of the tendency of stainless steel weld metal to pick up carbon from the carbon electrode.

Metallurgical, practical and economical considerations generally will give preference to one or several of the above major processes or to one of their modifications. For example, stainless steel sheets up to a thickness of about 1/8 in. are generally welded by the oxyacetylene, atomic hydrogen or inert-gas tungsten-arc welding processes, the last being the most commonly used. Stainless steel plates of more than 1/4 in. in thickness usually are welded by the shielded metal-arc welding process. However, inert-gas metal-arc welding with consumable stainless steel electrodes is also becoming increasingly

Table 7—Typical Welding Recommendations for Shielded Metal-Arc Welding of Butt Welds in Austenitic Stainless Steels of Various Sheet and Plate Thickness

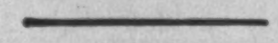
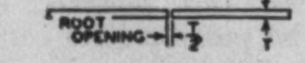
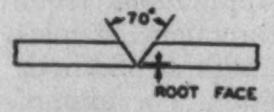
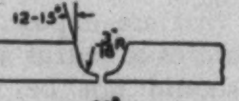
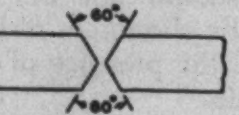
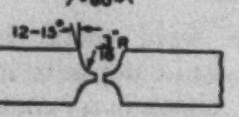
Sheet or Plate Thickness, In.	Number of Passes	Electrode Dia In.	
		Root Pass	Subsequent Passes
Up to 1/32	1	3/64	—
1/16	1	1/16	—
3/32	1	3/32	—
1/8	1	1/8	—
1/8	2	3/32	3/32
3/16	1	5/32	—
3/16	2	1/8	1/8
1/4	2	5/32	5/32
3/8	2	5/32	3/16
3/8	2 or more	5/32	5/32[1]
1/2	3	5/32	1/4
1/2	4 or more	5/32	5/32[1]
5/8	4	5/32	5/16
5/8	5 or more	5/32	5/32[1]

Electrode Dia In.	Electrode Consumption, Lb per Ft	Current		Arc Voltage
		Flat and Horizontal, Amp	Vertical and Overhead, Amp	
3/64	0.06	15–35	15–25	18–21
1/16	0.10	30–60	25–40	20–23
3/32	0.18	50–100	45–65	22–25
1/8	0.30	70–130	70–95	23–26
5/32	0.50	100–170	100–125	24–27
3/16[2]	0.75	150–200	130–145	24–28
1/4[2]	1.2	200–290	Not recommended	26–30
5/16[2]	1.5	250–400	Not recommended	28–32

[1] *Continuing the welding operation with same size electrode as used for the root deposit is often preferred practice.*

[2] *For vertical and overhead welding, the electrode diameter should not exceed 3/16 in.*

Table 8—Recommended Joint Designs for Shielded-Metal-Arc Welding of Butt Joints in Austenitic Stainless Steels

Thickness, In.	Joint Design	Notes
Up to 1/16		Square butt-type joint—butted tightly without root opening
1/16–3/16		Square butt-type joint—½ T root opening
3/16–1/2		Single-V groove joint—1/16-in. root face, 1/32- to 1/16-in. root opening
1/2 to 3/4		Single-U groove joint—1/8-in. root face, 1/16- to 1/8-in. root opening
Over 3/4		Double-V groove joint—no root face, butted tightly or up to 1/16-in. root opening
		Double-U groove joint—1/8-in. root face, 1/16- to 1/8-in. root opening

popular since it allows rapid welding rates and produces welds which are clean and smooth. When production set-ups are available, the medium and heavy gages are often most quickly and economically welded by means of the submerged-arc process.

Cleanliness of the base metal and of the jigs and fixtures is very important to prevent contamination of the stainless steel weld deposit. Alignment by means of suitable jigs and fixtures or careful tack welding is essential.

Shielded Metal-Arc Welding

Either direct current or alternating current may be used. However, low voltage direct current with reversed polarity (*i.e.,* work negative and the electrode positive) is preferred by most welders over welding with alternating current.

Up to about 5/32 in., the core wire diameter of the electrode should be approximately equal to, or slightly less than, the thickness of the base steel to be welded. Typical welding recommendations for butt joints are given in Tables 7 and 8. Although two weld beads are usually preferred for welding plates ⅛ in. in thickness and heavier, single bead welds can be successfully made for plates up to a thickness of about ¼ in. Some caution is necessary with electrodes 3/16 in. in diameter and heavier since they produce weld deposits relatively susceptible to hot cracking and porosity. On the other hand, when both surfaces are to be polished, welding from both sides is sometimes preferred even for sheets as light as 3/32 in., since it results in smoother weld beads and reduces polishing costs.

Between passes of multiple pass welds the slag should be removed and the weld should be cleaned with a stainless-steel wire brush. Moreover, in all multiple pass welding of single "V" or "U" grooves, after the groove has been filled in, the root pass should be ground, chipped or chamfered out from the back down to clean, solid metal before the final backing weld is to be deposited.

String beading is generally preferred over weaving since weaving or puddling may lead to porosity and to "stirring-in" of slag particles, may increase the tendency for hot-cracking, and, by introducing more heat into the base steel, may increase the severity of the intergranular chromium carbide precipitation of the nonstabilized grades. Moreover, a planned welding sequence is advisable on plates heavier than 1 in. The backstep and block sequence is generally preferred. For double "V" or "U" joints an alternate layer sequence should be used between opposite sides. For best results, the electrode should be held about 60 deg to the axis of the groove in the welding direction. When plates of different thickness are welded, the arc should be directed more towards the heavier plate in order to provide equal heating of both plates.

Submerged Arc Welding

Although the submerged arc welding process is particularly suitable for welding stainless steel plates of medium and heavy thickness, sheets as light as 1/16 have been satisfactorily welded. The basic process is characterized by deep penetration and considerable fusion. The resulting weld metal may consist of as much as or more than one-half base steel which has melted and mixed with the metal from the filler wire. Because of the deep penetration characteristics of this welding process, much smaller welding grooves and root openings are generally used than with other arc welding processes. This reduces edge preparation and saves in the consumption of welding rod. Penetration is also influenced by the particle size of the flux used. The finer the particle size the deeper will be the penetration.

Welding rods, in small and large coils, are commercially available in diameters from 3/32 to ¼ in. Although one welding pass is usually sufficient for plate thicknesses up to about ½ in., welding in two passes is generally preferred, with one pass deposited on each side.

Whereas in the conventional submerged-arc welding equipment only one welding rod is used, a so-called multiple electrode process is gaining in popularity where twin welding arcs are produced between two welding rods and the work. The two welding rods are electrically connected in series producing a current flow electrode-work-electrode. Whereas the conventional single welding rod process is characterized by deep penetration and considerable fusion, in the multiple electrode process penetration values may amount to only about 10 or 20%. This is of particular advantage when low and medium alloy steels are to be welded with stainless steel electrodes, or when mild, low and medium alloy steels are being surfaced (overlaid) with stainless steels.

Atomic-Hydrogen Welding

Although atomic-hydrogen welding was widely used a few years ago in the welding of light gage stainless steel sheet varying from 3/32 in. up to about ⅛ in. in thickness, it is now being more and more replaced by the inert-gas processes. Sheet up to about 1/16 in. is usually welded without welding rods by butting square edges tightly together. Where a slight reinforcement is desirable, the abutting edges can be bent slightly or flanged to provide for added weld metal. Sheets above 1/16 in. in thickness usually are welded with the aid of bare welding rods of the same composition as the base steel. Fluxes generally are not used.

Inert-Gas Welding

Two major processes are used in the inert-gas welding of stainless steels: (1) inert-gas carbon- or tungsten-arc welding, and (2) inert-gas metal-arc welding with consumable electrodes. Whereas nonconsumable carbon or tungsten electrodes are used in the former, a consumable stainless-steel electrode is used in the latter.

The inert-gas carbon- or tungsten-arc welding process is one of the most important processes used to weld thin stainless steels up to a thickness of about ⅛ in. The arc is generally struck between the work and a single (nonconsumable) carbon or tungsten electrode, and helium or argon gas (monoatomic) is flowed around the electrode and over the work to protect the weld metal from contamination by the atmosphere and thus eliminating the necessity of fluxes. Since the welding heat is concentrated on a very narrow area, distortion generally is less than it would be if the weld were made by any of the other arc or gas welding processes. Because of the narrow heating zone, stainless steel sheets as thin as 0.005 in. can be welded with automatic equipment. Manual or automatic procedures can be employed for sheets over 0.015 in. thick.

Direct current with straight polarity or alternating current with high-frequency stabilization are used for stainless steels. Direct current, straight polarity, however, allows deeper penetration and greater welding speeds.

Tungsten electrodes generally are preferred over carbon electrodes. In fact, the recently developed thoriated tungsten electrodes are a considerable improvement over the "straight" tungsten electrodes. Carbon electrodes, however, may be used for welding sheets less than 0.10 in. thick where the arc current is below 100 amp. Higher currents may result in carbon pick-up.

Typical welding recommendations are given in Tables 9 and 10. The speeds recommended in Table 10 are for conditions where trouble-free welds with a finished surface are desired as, for example, a small item or where articles require special set-up. Welding speeds about 2 to 3 times faster may be used for mass fabrication set-ups of tubes, barrels, automotive parts, etc., where the discarding of a few defective weldments is more economical than production without reject but a much slower welding speed. On the other hand, current and speed values in the lower end of the recommended range are suggested for inexperienced welders and for badly fitting work.

Although the inert-gas metal-arc welding process with consumable electrodes (also called "Sigma" or "Aircomatic" welding) has been developed only a few years ago, it is becoming more and more important for welding stainless steel plates above a ¼ in. thickness. The transfer of weld metal through the shielded-arc column increases the efficiency of heat input to the base steel over that obtained by the carbon- or tungsten-arc process and allows very rapid welding speeds. Still higher welding speeds can be obtained by using an oxyargon gas mixture in which from 1 to 5% oxygen has been added to the conventional argon gas.

Fluxes, such as "Inertic", are widely recommended to prevent oxidation of the underside of the weld.

Oxyacetylene Welding

Oxyacetylene welding is used for stainless steel sheets up to about 1/16 in. Heavier gages may also be successfully joined by this process, particularly where short-circuiting might occur in electric-arc welding because of the electrode length, when welding must be performed in very confined locations. However, when possible, the shielded metal-arc and inert-gas arc processes are always preferred.

Sheets up to about 1/16-in. thick are tightly butted together and welded without welding rods. The abutted edges may be turned up to equal the thickness of the sheet. Although a neutral flame would be most desirable, a flame with a slight excess of acetylene is more commonly used. Too much acetylene may produce serious carburization. On the other hand, an excess of oxygen tends to result in oxidation and porosity.

Forehand (left hand) welding is generally preferred since it causes some preheating of the base steel, facilitates subsequent fusion, and accelerates the cooling rate of the solidified weld metal. Backhand welding, however, is often more practical for welding the heavier

Table 9—Recommended Designs for Inert-Gas Carbon- or Tungsten-Arc Welding of Butt Joints in Austenitic Stainless Steels

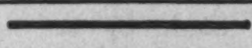
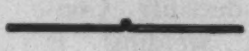
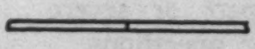
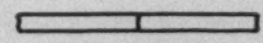
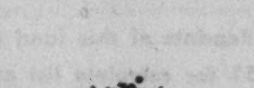
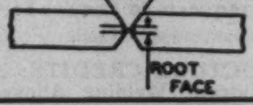
Thickness, In.	Filler Rod Used	Number of Passes	Joint Design	Notes
Up to 1/32	No	1		Square butt-type joint—no root opening, flat backup strip
				Edges turned up to equal thickness of sheet—no root opening
1/32–1/16	Sometimes	1		Square butt-type joint—no root opening, groove backup strip
1/16–5/32	Yes	1		Square butt-type joint—no root opening, backup strip may be omitted
5/32–1/4	Yes	1		Square butt-type joint or single-V groove joint—no root opening, a 1/16-in. root face is sometimes recommended when "V" grooves are used; backup strip may be omitted
Over 1/4	Yes	2 or more		Double-V joint—no root opening, a 1/16- to ⅛-in. root face is sometimes recommended; backup strip may be omitted

Table 10—Typical Welding Recommendations for Semi-Automatic and Automatic Inert-Gas Shielded Arc Welding of Austenitic Stainless Steels

Sheet or Plate Thickness, In.	Dia of Tungsten Electrode, In.[1]	Filler-Rod Dia, In.	Gas Consumption Cu Ft/Hr		Current Requirements, Amp		Voltage, V	Welding Speed, In./Min	
			Helium	Argon	Helium	Argon		Helium	Argon
1/100	1/32	Not used	[3]	10–15	—	5–15	15	—	8–10
1/64	1/32	Not used	[3]	10–15	20–40	30–60	15	15–30	15–30
1/32	1/16	Not used	15–20[3]	10–15	40–80	75–150	15	20–40	15–30
1/16	3/32 or 1/8	Not used	15–20	10–15	100–225	150–275	10–12	40–70	25–50
1/64	1/32	1/16[2]	[3]	10–15	20–40	30–60	15	20–40	20–40
1/32	1/16	1/16[2]	15–20[3]	10–15	40–80	75–150	15	30–50	20–40
1/16	3/32 or 1/8	1/16 or 3/32	15–20	10–15	100–225	150–275	10–12	40–80	30–60
3/32	1/8	3/32 or 1/8	20–25	10–20	200–275	250–350	10–12	30–60	20–50
1/8	1/8 or 3/16	3/32 or 1/8	20–25	15–20	275–350	350–450	10	20–40	15–30
5/32	5/32	1/8 or 3/16	25–30	15–20	275–375	375–500	10	20–40	15–30
3/16	3/16	1/8 or 3/16	25–30	15–25	300–400	400–600	10	15–30	10–30
3/16	3/16	1/8 or 3/16	25–30	15–25	300–400	400–600	10	15–30	10–20

[1] *Much larger diameters are generally recommended for carbon electrodes.*
[2] *Not recommended.*
[3] *Argon gas welding preferred. When helium is used, thoriated tungsten electrodes should be employed.*

sections above about 1/8 in., particularly when high welding speeds are desired.

A suitable flux has to be applied to the underside of the joint close to the edges being welded.

Resistance Welding

Since the electrical resistance of the austenitic stainless steels is about six times as high as that of mild steels, they are particularly suitable for welding by the resistance welding methods. Since heating by the current is rapid and is confined to a narrow area, the tendency toward warping and buckling is minimized. The short heating cycles also minimize carbide precipitation. The resulting weld joints are usually tough and exhibit excellent ductility.

Welds in the martensitic and ferritic stainless steels, made by resistance welding, usually exhibit poor toughness and ductility. Consequently, resistance welding is not recommended if the joint will be subjected to impact or severe pounding or bending operations.

Brazing

Stainless steel can be readily brazed. Although silver brazing alloys are generally preferred, copper-base alloys which may or may not contain zinc are also used. With copper-base alloys, excessive heating of the base metal should be avoided, since the copper in the brazing alloy may cause intergranular penetration of the stainless steel, seriously reduce ductility, and cause brittleness. Most brazing alloys will change their color in the atmosphere and, particularly, under corrosive conditions so that most brazing alloys generally do not match the color of the stainless steel. When stainless steels for elevated temperature applications have to be brazed, a nickel-chromium brazing alloy has been suitable for temperatures up to 1800 F. A silver-manganese alloy can also be used for applications up to 900 F.

Since borox and boric acid fluxes are unsuitable for stainless steels, special proprietary fluxes have to be used.

Soldering

Because of the tightly adhering oxide film, stainless steels are more difficult to solder than copper alloys and carbon steels. Tin-lead solders containing about 50 to 60% tin seem to give the best results. Strong fluxes are necessary and are available under various proprietary names. Proper heating is important. Serious embrittlement may occur if the joint temperature exceeds 700 F. Pretinning of the surfaces to be joined generally is desirable.

References

The welding summary presented in this Manual is based on the following detailed correlated review articles sponsored by the Literature Advisory Committee of the Welding Research Council, which are detailed discussions of published and unpublished information on the physical and welding metallurgy of stainless steels:

"Alloying Elements in Chromium Nickel Stainless Steels," *The Welding J.*, Vol. 29, 1950, Research Suppl., pp 361-s to 404-s.

"Physical Metallurgy of Austenitic Stainless Steels," *The Welding J.*, Vol. 29, 1950, Research Suppl., pp 577-s to 621-s.

"Physical and Welding Metallurgy of Chromium Stainless Steels," *The Welding J.*, Vol. 30, 1951, pp 209-s to 250-s.

"Welding Copper-Bearing Stainless Steels," *The Welding J.*, Vol. 30, 1951, Research Suppl., pp 341-s to 347-s.

"Copper in Stainless Steels," *Welding Research Council Bulletin*, No. 9, Aug. 1951.

"Stainless Steels Weld Deposits on Mild and Alloy Steels," *The Welding J.*, Vol. 31, 1952, Research Suppl., pp 37-s to 64-s.

"Stainless Clad Steels," *The Welding J.*, Vol. 31, 1952, Research Suppl., pp 142-s to 160-s.

"Stainless-Steel Applied Liners," *The Welding J.*, Vol. 31, 1952, Research Suppl., pp 321-s to 337-s.

"Thermal Fatigue and Thermal Shock," *Welding Research Council Bulletin*, No. 10, Apr. 1952.

"Welding Processes and Procedures Employed in Joining Stainless Steels," *Welding Research Council Bulletin*, No. 14, Sept. 1952.

"Testing of Stainless Steel Weldments," in print.

Reprints of this (and other) Manuals are available at 25¢ each until supply is exhausted. See page 251 for complete list of available Manuals. Write for quotations on quantities of 100 or more. Address requests to Reader Service Dept., MATERIALS & METHODS, 330 W. 42nd St., New York 36, N. Y.

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Materials Engineering File Facts

MATERIALS & METHODS
May • 1953
Number 252

Materials Data Sheet

Industrial Glasses

The two most important properties of glass are its ability to transmit light and its high resistance to chemical attack. Although many special glasses are produced, the following are the principal types:

Type	Fused Silica	96% Silica	Soda-Lime Glasses: Plate	Soda-Lime Glasses: General Purpose	Alumino-Silicate
PHYSICAL PROPERTIES					
Density, Lb/Cu In.	0.079	0.078	0.09	0.089	0.091
Softening Point, F (Approx)	3050	2800	1330	1285	1675
Thermal Cond, Btu/Hr/Sq Ft/Ft/F @ 212 F	0.80	0.80	0.53	0.53	—
Coeff of Exp per ° F, 32–570 F	3.0×10^{-7}	4.5×10^{-7}	48×10^{-7}	51×10^{-7}	23×10^{-7}
Spec Ht, Btu/Lb/F	0.185	0.185	0.20	0.20	—
Elect Res, Ohm-Cm @ 212 F	$>10^{15}$	$>10^{15}$	—	4×10^9	$>10^{15}$
Power Factor, 68 F 1 MC, %	0.025	0.02–0.04	0.80	0.90	0.37
Dielectric Constant, 68 F 1 MC	3.75	3.8	7.4	7.2	6.3
Thermal Stress Resistance[1]	—	390	—	65	85
Thermal Shock Resistance[2]	Very high	Very high	135	125	240
MECHANICAL PROPERTIES					
Mod of Elasticity, Psi	10×10^6	9.7×10^6	$9\text{–}10 \times 10^6$	$9\text{–}10 \times 10^6$	12.7×10^6
Normal Work Stress (Annealed) Psi	1000	1000	1000	1000	1000
THERMAL TREATMENT					
Annealing Temp, F (Stress Relieving)	2080	1670	1010	950	1315
FABRICATING PROPERTIES	Glass can be ground or polished without great difficulty. Machining is limited to sawing or drilling. Sawing is readily accomplished with an impregnated wheel. Drilling is difficult, but is done with special carbide-tipped drills using kerosene as a lubricant.				
Joining	Glass can be joined by heat-sealing using a blast-lamp, gas torch or by electric heating. Parts must have closely similar coefficients of expansion or intermediate pieces having intermediate coefficients must be used. Glass-to-metal seals are made by this latter process, also.				
Highest Service Temp F, Annealed	1650	1500	900	840	1200
Tempered	—	—	550	480	840
CORROSION RESISTANCE	Glass is attacked by hydrofluoric acid, hot concentrated phosphoric acid and strong alkalies. It is resistant to most other chemicals.				
USES	Ultra-violet energy transmission, chemical apparatus, thermocouple protection tubes, laboratory apparatus.	Ultra-violet energy transmission, chemical reaction vessels, thermocouple protection tubes, laboratory apparatus.	Sheet and plate glass, molded glassware, bulbs for electric lamps, bottles, vials, fluorescent lamp tubing.		

(*Continued on page 137*)

take a closer look at

Stainless STEEL PIPE SIZE Schedules

Don't be "penny wise and pound foolish" where stainless steel piping is concerned. The most economical choice does not always imply the least initial cost as working pressure, methods of joining, installation costs and allowance for loss by corrosion are critical factors. This is particularly true where costs resulting from failures in service—replacement of equipment and lost production due to down time—may exceed the initial cost of the piping.

Figure A

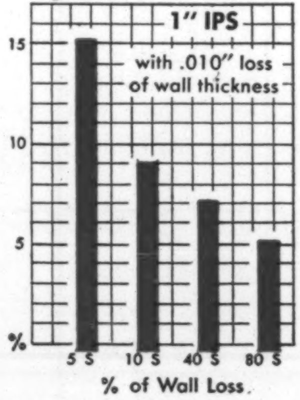


Figure B

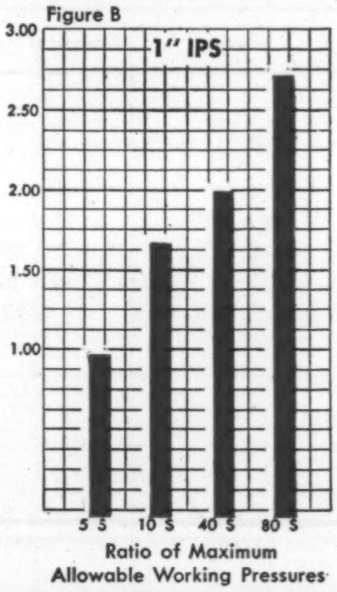


Figure C

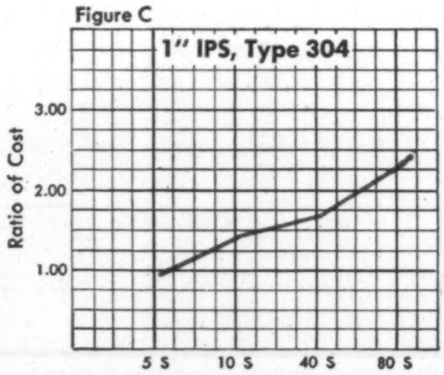
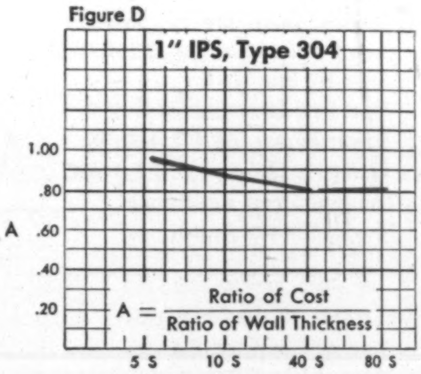


Figure D



CORROSION RESISTANCE

For long service life it is advisable to allow for some loss in wall thickness where stainless piping is employed to combat severe corrosion. As shown in Figure A even a small loss means an appreciable percentage loss of wall thickness in the lighter weight schedules.

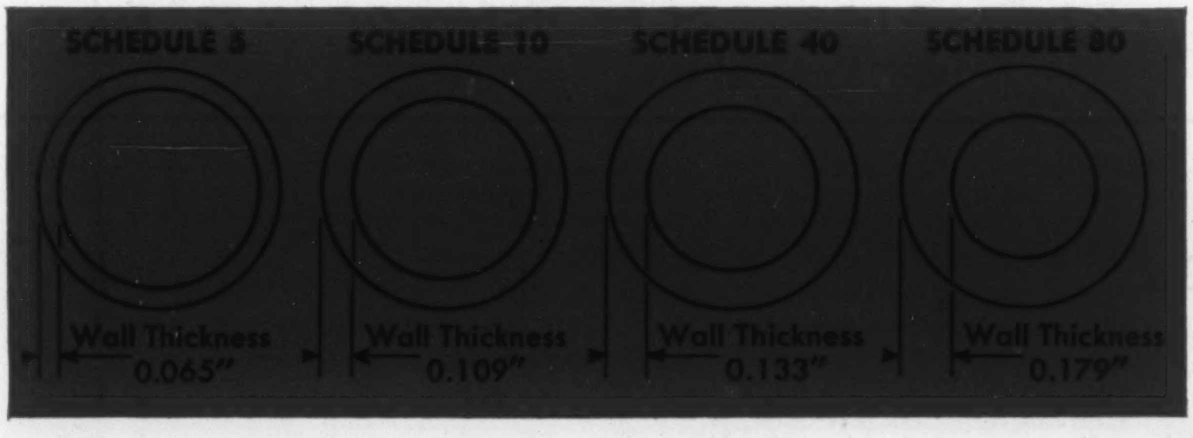
WORKING PRESSURES

As shown in Figure B, the heavier pipe schedules permit higher working pressures, thus perhaps permitting the use of smaller diameter piping, or offering greater flexibility for subsequent changes in operational procedures.

COSTS

Although the lighter schedules cost less, as shown in Figure C, you actually get more for your money with the heavier schedules because the ratio of increase in cost is *less* than the ratio of increase of wall thickness (Figure D).

1" IPS



Methods of Joining & Installation Costs

From the standpoints of economy and ease of installation, it is extremely important that attention be given to methods of joining, fittings, etc. because:

1. Schedule 40 IPS is the lightest weight pipe specifically designed for threading.
2. Fittings which provide a good thread and also afford structural strength at the joint are not commercially available for lighter weight pipe.
3. Field welding of thin wall pipe is difficult.
4. Misalignment of connections can cause high installation costs.

While various types of fittings are available for the lighter weight pipe schedules, they should be examined carefully as to initial cost, installation cost, working pressure permitted and ease of adaptation to existing lines.

Whatever your stainless piping problems, Mr. Tubes—your B&W Tube representative—can provide valuable assistance. Consult him for advice on the stainless piping or tubing that will afford optimum cost-life ratio under your service conditions.

TA-1709 (P)

B&W SEAMLESS and WELDED TUBES

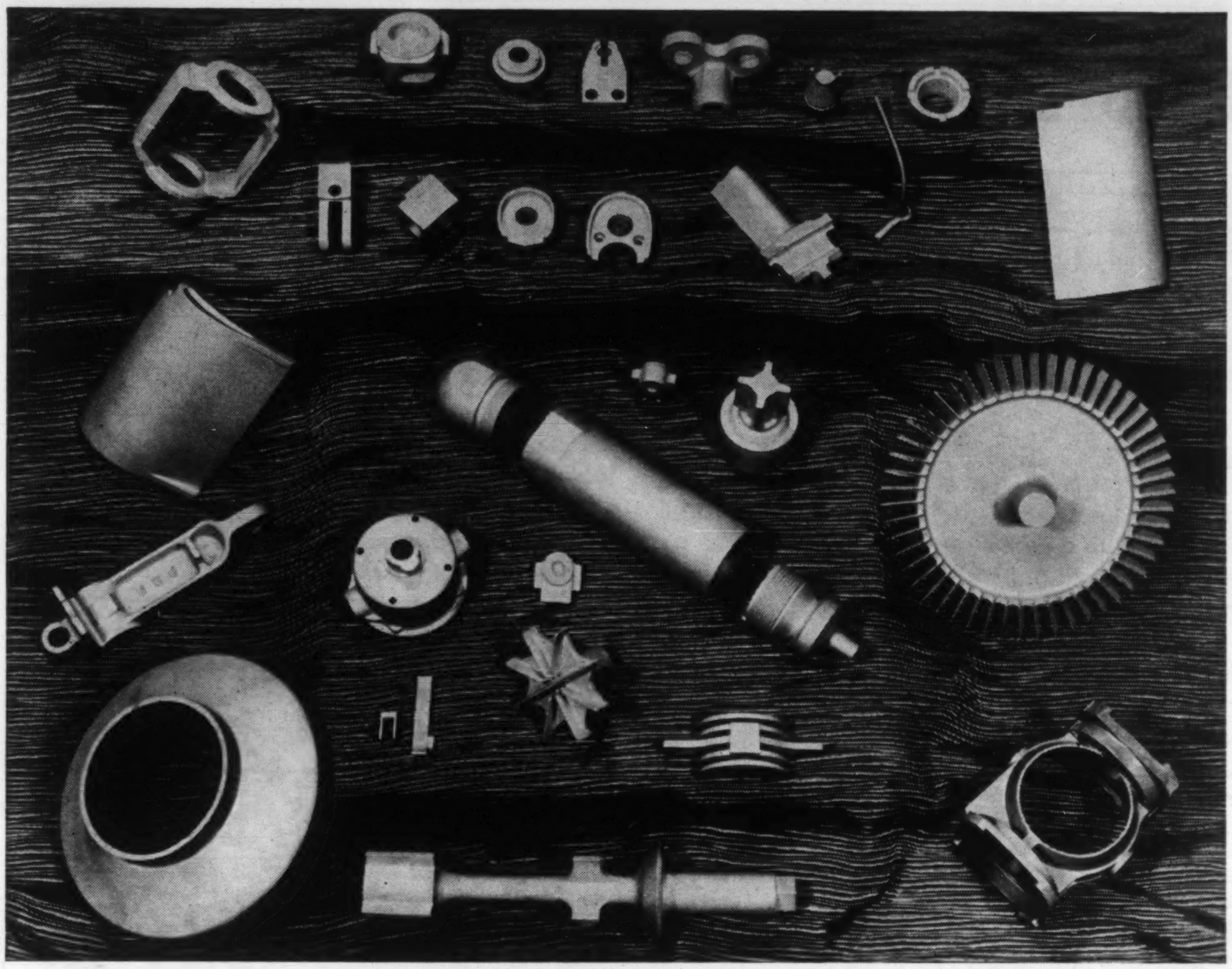
THE BABCOCK & WILCOX COMPANY
TUBULAR PRODUCTS DIVISION
Beaver Falls, Pa.—Seamless Tubing; Welded Stainless Steel Tubing
Alliance, Ohio—Welded Carbon Steel Tubing

Materials Engineering File Facts

MATERIALS & METHODS
May • 1953
Number 252

	Borosilicate Glasses			
Type	Low Expansion Chem. Resistant	Baking Ware	"Kovar" Sealing	Low Electrical Loss
PHYSICAL PROPERTIES				
Density, Lb/Cu In.	0.080	0.081	0.082	0.77
Softening Point, F (Approx)	1500	1425	1300	—
Thermal Cond, Btu/Hr/Sq Ft/Ft/F @ 212 F	0.67	—	—	0.67
Coeff of Exp per ° F, 32–570 F	18.5×10^{-7}	20×10^{-7}	25×10^{-7}	18×10^{-7}
Spec Ht, Btu/Lb/F	0.195	0.195	—	—
Elect Res, Ohm-Cm @ 212 F	10^{12}	—	3×10^{13}	$>10^{15}$
Power Factor, 68 F 1 MC, %	0.46	0.28	0.26	0.06
Dielectric Constant, 68 F 1 MC	4.6	4.7	5.1	4.0
Thermal Stress Resistance[1]	—	—	—	—
Thermal Shock Resistance[2]	320	—	—	—
MECHANICAL PROPERTIES				
Mod of Elasticity, Psi	9.8×10^{6}	—	—	6.8×10^{6}
Normal Work Stress (Annealed), Psi	1000	1000	1000	1000
THERMAL TREATMENT				
Annealing Temp, F (Stress Relieving)	1020	975	890	910
FABRICATING PROPERTIES	Glass can be ground or polished without great difficulty. Machining is limited to sawing or drilling. Sawing is readily accomplished with an impregnated wheel. Drilling is difficult, but is done with special carbide-tipped drills using kerosene as a lubricant.			
Joining	Glass can be joined by heat-sealing using a blast-lamp, gas torch or by electric heating. Parts must have closely similar coefficients of expansion or intermediate pieces having intermediate coefficients must be used. Glass-to-metal seals also are made by this latter process.			
Highest Service Temp F, Annealed	900	840	800	810
Tempered	550	500	420	450
CORROSION RESISTANCE	Glass is attacked by hydrofluoric acid, hot concentrated phosphoric acid and strong alkalies. It is resistant to most other chemicals.			
USES	Heat exchanger tubes, chemical apparatus, cooking-ware, electrical insulators, sight and gage glasses, containers for chemicals and medicinals, metal sealing, industrial piping, industrial glassware requiring thermal resistance, special lighting ware, heat resisting lenses.			

(Continued on page 139)



Inco-Cast precision investment castings offer a practical way to make a wide variety of difficult-to-machine shapes including: thin vanes, wing sections, non-critical gear teeth, slots and threads.

How you can save up to 50%...on small parts

With Inco-Cast precision investment castings, others are saving as much as 50 percent of the production cost on small parts.

Perhaps you can, too. If you need small parts with complex internal sections, shallow blind holes, unmachinable cavities or other shapes that are costly to make, it may pay you to investigate precision casting. For precision casting lends itself to economical production of intricate shapes where tolerances as close as plus or minus .005″ per linear inch are needed.

Inco-Cast precision castings not only save you money—they make it possible for you to use extra strong and harder alloys for longer service life...

- You can reduce your machine shop bottleneck because they require little or no machining.
- They make possible the use of hard-to-machine metals.
- In many applications you can get parts made by precision casting that would be impossible to make by other methods.
- Frequently it's even possible to simplify your designs when you use precision castings.

If you have a problem with a part whose cost of production seems out of line—if it's a shape where a single casting might eliminate many machining operations — if you have a design that cannot be worked out economically—just send a blueprint or actual sample with an estimate of the quantity needed.

Inco casting specialists will analyze your problem and, if precision casting is a practical solution, they will give you an estimate of costs and their suggestion on the best alloy to use.

In the meantime, for more detailed information about this money-saving process, write for your free copy of "Investment Casting—Its Advantages and Practical Applications."

The International Nickel Company, Inc.,
67 Wall Street, New York 5, N. Y.

SOME ALLOYS PRECISION CAST BY INCO

Nickel-Base Alloys
Ferrous Alloys
Austenitic Stainless Steels
Martensitic Stainless Steels
Ferritic Stainless Steels
Carbon Steels
Alloy Steels
Tool Steels
Cobalt-Base Alloys

Inco Castings PRECISION, SAND, CENTRIFUGAL

INCO
TRADE MARK

Materials Engineering File Facts

MATERIALS & METHODS
May • 1953
Number 252

NUMBER 252 (continued)

INDUSTRIAL GLASSES

	Lead Silicate Glasses		
Type	Lamp Tubing	Thermometer	High Lead
PHYSICAL PROPERTIES			
Density, Lb/Cu In.	0.110	0.104	0. 54
Softening Point, F (Approx)	1160	1200	1075
Thermal Cond, Btu/Hr/Sq Ft/F @ 212 F	0.50	0.50	0.45
Coeff of Exp per ° F, 32–570 F	50 x 10^{-7}	47 x 10^{-7}	51 x 10^{-7}
Spec Ht, Btu/Lb/F	0.17	—	0.16
Elect Res, Ohm-Cm @ 212 F	10^{14}	—	$>10^{15}$
Power Factor, 68 F 1 MC, %	0.16	—	0.09
Dielectric Constant, 68 F 1 MC	6.6	—	9.5
Thermal Stress Resistance[1]	65	—	—
Thermal Shock Resistance[2]	120	—	—
MECHANICAL PROPERTIES			
Mod of Elasticity, Psi	9.0 x 10^{6}	—	7.6 x 10^{6}
Normal Work Stress (Annealed), Psi	1000	1000	1000
THERMAL TREATMENT			
Annealing Temp, F (Stress Relieving)	800	860	800
FABRICATING PROPERTIES	Glass can be ground or polished without great difficulty. Machining is limited to sawing or drilling. Sawing is readily accomplished with an impregnated wheel. Drilling is difficult, but is done with special carbide-tipped drills using kerosene as a lubricant.		
Joining	Glass can be joined by heat-sealing using a blast-lamp, gas torch or by electric heating. Parts must have closely similar coefficients of expansion or intermediate pieces having intermediate coefficients must be used. Glass-to-metal seals also are made by this latter process.		
Highest Service Temp F, Annealed	720	750	720
Tempered	380	400	360
CORROSION RESISTANCE	Glass is attacked by hydrofluoric acid, hot concentrated phosphoric acid and strong alkalies. It is resistant to most other chemicals.		
USES	Lamp tubing, electrical and electronic applications, thermometer tubing, metal sealing.		Electrical capacitors, x-ray shielding.

NOTES:

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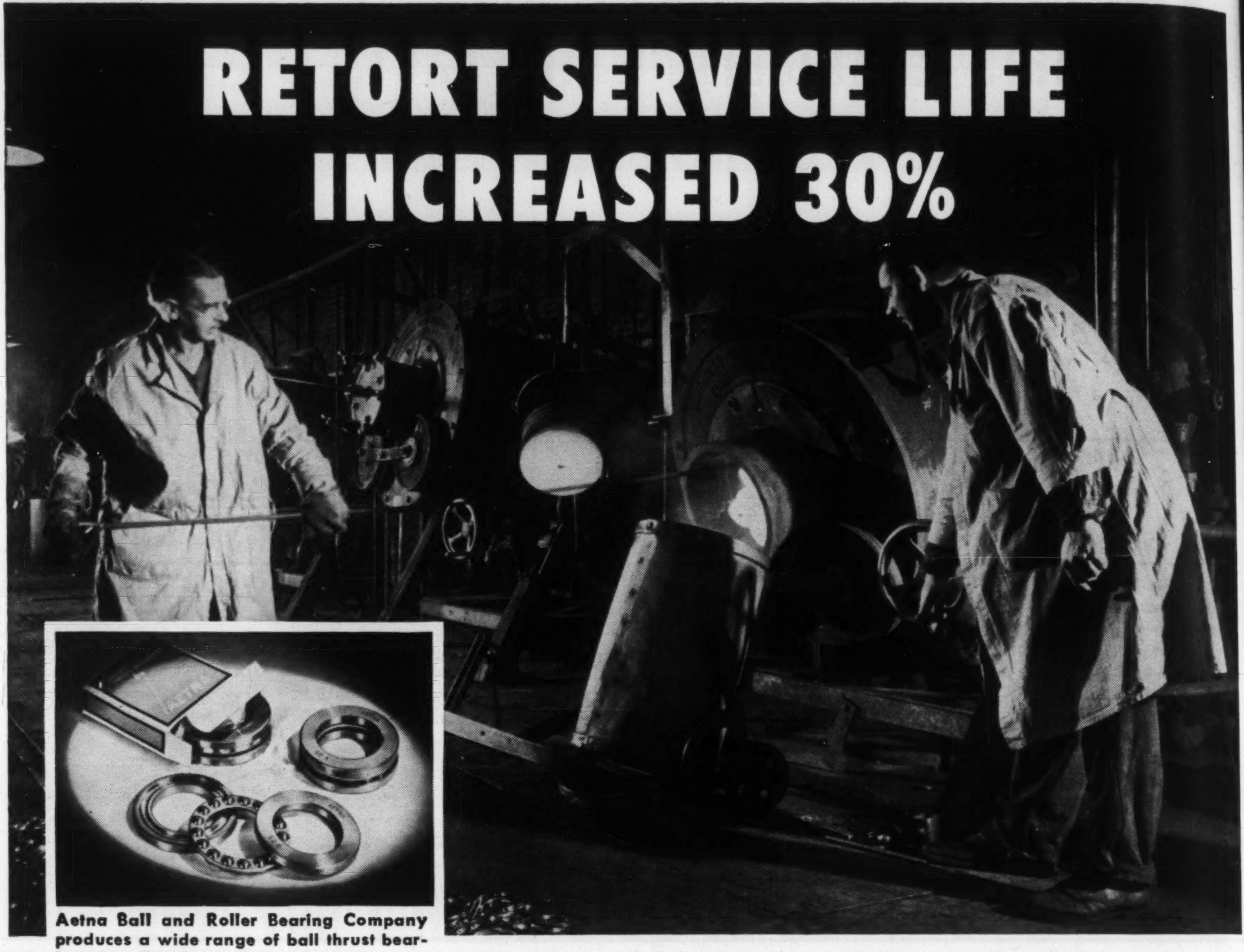
[1] *Measured by subjecting the two sides of tube or constrained plate to a temperature differential and measuring differential, causing a stress of 1000 psi on cooler surface.*

[2] *Measured by heating squares of annealed glass 6 in. by 6 in. by ¼ in. to a uniform temperature and dropping into cold water. Index is maximum temperature differential at which no breakage occurs*

Prepared with the assistance of Corning Glass Works

RETORT SERVICE LIFE INCREASED 30%



Aetna Ball and Roller Bearing Company produces a wide range of ball thrust bearings for all industry.

...when cast in THERMALLOY*

When you want longer service life from your heat treating parts . . . Thermalloy can be the answer. That profitable point was proved at the Aetna Ball and Roller Bearing Company in Chicago, Ill. This company found that *retort service life increased* 30% when cast in Thermalloy.

Shown above are workmen at the Aetna plant removing a batch of ball thrust bearing races from a Thermalloy retort. At this point, the temperature is normally 1750°F., with the heat treating cycle lasting about 5 hours. In operation 24 hours a day, service life of these Thermalloy retorts averages around 10,000 hours with some going full blast to nearly 15,000 hours.

Designed by Electro-Alloys engineers, the shape of this octagonal Thermalloy retort provides Aetna with a sounder casting that gives more uniform tumbling action with less marring of parts.

For retorts, furnace parts, trays, racks, pots, muffles—Thermalloy gives you more operating hours per dollar. Our engineers will help you select the right grade of Thermalloy, engineer the casting and foundry practices necessary to produce a high heat-resistant casting for lowest cost service life. Call in an Electro-Alloys engineer for full information or write Electro-Alloys Division, 4001 Taylor Street, Elyria, Ohio.

*Reg. U. S. Pat. Off.

AMERICAN
Brake Shoe
COMPANY

ELECTRO-ALLOYS DIVISION
ELYRIA, OHIO

New Materials and Equipment

Silicon Resin Base Finish

A new stain-resistant, highly flexible baking enamel, said to be 50% harder than previous standard enamels, has been announced by *The Glidden Co.*, Cleveland. Called Nubelon S, the coating's resistance to abrasion, corrosion and chemical action recommend it as a replacement for porcelain and galvanizing on such applications as kitchen and laundry appliances, metal furniture, prefabricated farm buildings, silos, screening, hospital equipment and concrete forms. In addition, its extreme flexibility is said to offer possibilities of finishing metal sheets before forming them into finished products.

According to the company, severe laboratory tests attest to the success of the new finish: It resisted staining of dyes—including mustard pigmentation, lipstick, coffee and fruit acids. No appreciable corrosion resulted after fog tests of 20% salt water solution for 4000 hr at 95 F. In addition, the coating showed excellent resistance to crude tall oil, carbon tetrachloride, formaldehyde, 63% ammonium nitrate (fertiziler solution) and 2-ethel hexoic acid.

The extent to which Nubelon S maintains its color under severe conditions and its extreme hardness and adhesion make it especially valuable as a white appliance finish. It is offered in various shades of whites, grays and yellows, as well as in blue, tan, green and red.

It is pointed out that the new coating is more expensive than current baking enamels and requires curing at 425 F. It compares favorably in cost with porcelain, while offering extreme flexibility and elimination of chipping and cracking problems.

Flexibility of Nubelon S is demonstrated as a coated wire is spiralled about a pencil with no cracking of the finish.

Arc Process Cuts Refractory Materials

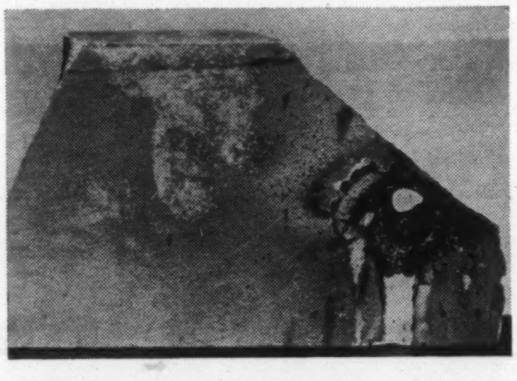
A new process for cutting and piercing refractory materials, stone, cement and concrete, trade named DynArc, has been announced by the *ChemoTec Div., Eutectic Welding Alloys Corp.*, 172nd St. and Northern Blvd., Flushing, N. Y. In demonstrating the new process recently, an arc rod was used for the first time upon nonconductive material and without a ground connection.

The DynaTrode creates its own arc. It requires no ground and it does not have to be struck upon metal. The arc, which will operate in mid-air as well as it will upon stone, resembles a flame in appearance.

Technically, DynaTrode is a self energizing arc rod. The heavy coating, especially formulated to give the thermo-chemical inter-reaction with the arc stream to react with the nonmetallic material, is reduced more slowly than the core. This forms a crucible or tube of coating through which the tremendous energy is concentrated into a fine tip, and its character has been changed by the disintegrating coating. The thermal ionization of the coating by the arc stream combined with the concentration produces the conditions necessary to pierce and melt the refractory material. These are properties of formulation and electrical and thermal equilibrium which produce a pre-determined thermo-chemical inter-reaction between the process of electrode disintegration and the components of the refractory material.

Wherever a d.c. welding machine is available of 250 amp or more capacity, the new process can be used. The multiplicity of equipment associated with high temperature and pneumatic cutting and drilling is absent. No compressors, air lines, oxygen tanks, pneumatic drills, are necessary. A conventional welding machine and a supply of DynaTrode rods are all the equipment required.

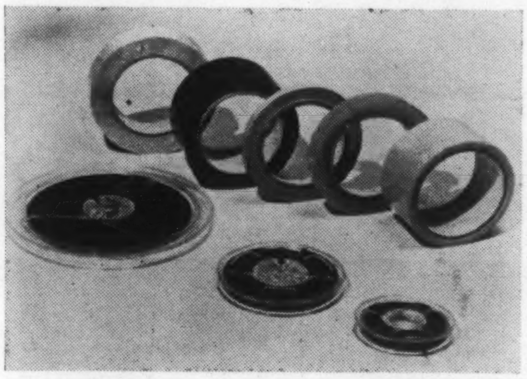
The new process is expected to open up new fields of application. When equipment has to be installed, the time-consuming drilling of holes in the concrete is eliminated. The DynaTrode will pierce the solid concrete in a matter of seconds, according to company statements.



A hole cut through refractory material by DynaTrode is shown here.

Pipes buried in masonry present a problem when they require attention. The problem is simplified with the new electrode. The masonry can be pierced and the pipe exposed. Then, should the metal pipe require cutting or piercing, the metal cutting electrode, CutTrode, can be exchanged for a DynaTrode and the whole operation carried out by the operator with a standard welding machine.

Polyester Film Has High Strength



As a recording tape, Mylar polyester film is long-lasting because it has greater strength in thinner gages than conventional films.

A new commercial film, said to be two to eight times as strong as other commercial film, and to have excellent electrical properties, has been announced by *E. I. du Pont de Nemours & Co., Inc.*, Wilmington, Del. Tensile strength of the "Mylar" polyester film is 25,000 lb psi—about 1/3 that of some high quality steels; its impact strength is claimed to be at least twice that of any known commercial film. Therefore, "Mylar" can be made in thinner gages—as fine as a quarter of one thousandth of an inch.

The film can be vacuum metallized with aluminum to form a strong combination which can be used in capacitors or condensors. Capacitors use quarter mil (0.0025 in.) film. The thin film, combining great strength with excellent electrical properties, makes possible smaller electrical equipment. Capacitors can be further reduced in size if the film is vacuum metallized to take the place of foil.

Suitable for recording tape and many types of industrial tapes, the new film can also be used for industrial wrapping and as an electrical insulation tape. "Mylar", which requires no plasticizer, has great dimensional stability. As a recording tape, it is long-lasting; because it has greater strength in thinner gages than conventional tapes, it permits more footage per reel.

At present, the polyester film is being made on an experimental basis at the company's Yerkes Research Laboratory.

Wrinkle Finishes with Improved Color Stability

Wrinkle finishes in pale shades and pastel colors are said to be more practical than ever before with a new line of Rinkeloid wrinkle finishes having exceptional color stability, announced by *Standard-Toch Chemicals, Inc.*, Products Finishes Div., 2600 Richmond Terrace, Staten Island 3, N. Y.

Because of improved color stability and pattern control during baking, normal variations in oven temperature will not result in variation in Rinkeloid color. Blacks, grays and browns will not tolerate as much as 25-deg differences in oven temperature without the usual widely varying color tones. Blacks, in particular, will not develop the undesirable brownish appearance which tends to reduce their attractiveness.

With the new resin, delicate pastel colors such as pale cream, blue, green, ivory and pink are easily produced. These colors are achieved without the usual brownish hue that results with heat-sensitive wrinkle-base resins.

The ease with which this new line of finishes can be controlled is expected to broaden the use of pale colors on office equipment, appliances, photographic equipment and similar products.

Micro Inch Finishes Applied to Metal Surfaces

This new processing technique effects micro inch finishes on a wide variety of metal surfaces.

Stainless steel, aluminum, monel, inconel, carbon steel, and other metal or metal alloy plates, sheets and coils can be finished to within micro-inch specifications and in a wide variety of surfaces not available from regular mill sources by a highly developed processing technique, according to information made available by *Apollo Metal Works*, Dept. M-4, 66th Place and S. Oak Park Ave., Chicago 38. The scope of application includes home and commercial appliances—cabinet trim, sink and range tops, packing house and food processing equipment, instrument panels, display signs, etc.

In addition to minute tolerance control of the finish, the processing technique utilizes a scientifically designed process to cool and clean the metal during polishing. This precludes the possibility of undesirable metallurgical reaction, as well as distortion or warping. Since the coolant is kept in constant flow and carefully filtered, even the tiniest abrasive particles are carried away, thus reducing grain marks and flaws to an absolute minimum. All surfaces are finished end to end.

Sheet and plate can be finished in sizes to 48 by 144 in., gages 0.018 to 0.375 in. Coils can be finished in widths from 24 to 36 in., gages 0.025 to 0.050, in standard mill lengths.

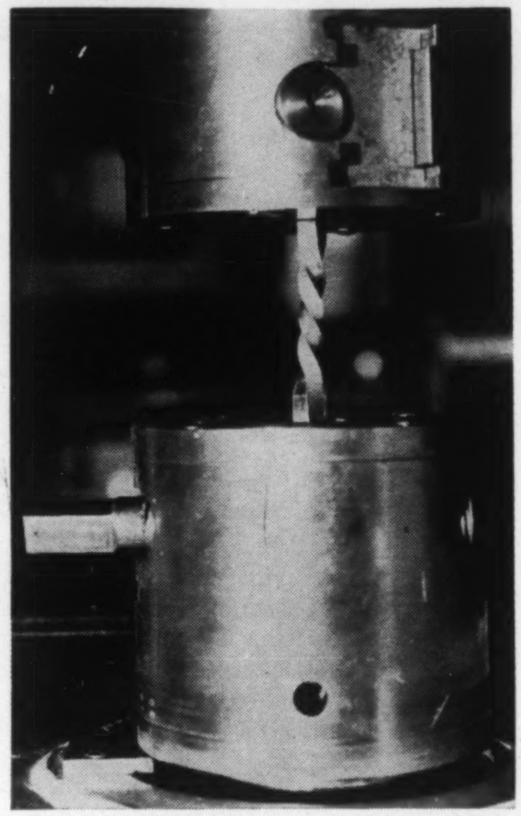
Metal Powder Features Great Ductility

Development of a new iron powder metal having improved ability to withstand high stresses without cracking has been announced by *Amplex Div., Chrysler Corp.*, Detroit 31. According to the company, the new development, Steel Oilite, has several times the ductility of previous iron powder products and makes possible many new uses for such material. The new material has physical properties that are comparable to mild carbon steel, such as SAE 1010, 1020 or 1030. It is also said to have two to three times the ability to bend over other metal powder parts produced by the Amplex Div.

Iron powder parts for regular usage will withstand a pressure of approximately 35,000 lb psi, while the new product withstands up to 70,000 lb. Moreover, it is not brittle, and can be bent or twisted without breaking.

The new product, because of its great ductility and strength, can be used for finished machine parts such as gears, cams, brackets and lever arms. Steel Oilite, while retaining some porosity, is not intended for self-lubricating applications such as may be a requisite for other Oilite products.

Parts of the new material can be plated by any of the normal processes. The material can be hardened by direct quenching or carburized and hardened.



Ductility of the new iron powder metal is shown here where pressure is exerted to twist the metal powder part two full turns.

Free Machining Screw Steel Offered

A new, free-machining screw steel for use in the making of screws, nuts, studs, bolts and other small machined products is now being produced by the open hearth process at *Jones & Laughlin Steel Corp.*, Gateway Center, Pittsburgh 30. The new steel is furnished in the form of cold-finished bars.

According to the company, tests and production trials already have proved that the new steel, designated the J&L 1200 series, gives greater uniformity, superior machinability, and a higher quality finish than conventional screw stock. Greater uniformity of the steel is said to be the result of the closer control of chemistry and temperature and the larger heat size possible in the open hearth furnace.

The new 1200 series is of analysis comparable to the 1200 series steels listed by the American Iron and Steel Institute and approved by Federal agencies. It meets specifications of the Society of Automotive Engineers' 1100 series listings.

Epoxide Resin Bonds Nonporous Surfaces

Development of a new epoxide resin adhesive suitable for bonding nonporous surfaces has been announced by the *Borden Co.'s* Chemical Div., 350 Madison Ave., New York 17. The product, Epiphen XR-823, is claimed to have shown excellent results in bonding metal, glass, natural or synthetic rubber, ceramic materials and wood, phenolic and glass fiber laminates, either to themselves or in various combinations. The cured bond is resistant to boiling water, acids, alkalis and most organic solvents.

When unfilled resin is used, Epiphen XR-823 can be used in the production of lenses, since it is transparent. This type of resin is also recommended for any casting and coating operations where shrinkage cannot be tolerated. The excellent wetting properties, fidelity, minimum shrinkage, high dielectric and mechanical strengths and high heat resistance of cast epoxides have resulted in their wide utilization for potting electronic assemblies, resistors and other uses in the electrical and electronic fields.

Test kits, containing 2 oz of rezin, plus the necessary catalyst and filler, are available for industrial firms at a cost of $1.50 from the company.

This test kit of Epiphen XR-823 is being offered to firms faced with unusual bonding problems.

New Materials and Equipment continued

Deburring Machine for Circular Pieces

A new turntable type deburring machine for rapid deburring of compressor stator rings, half rings or other ring sections of jet turbines, has been developed by *Grinding & Polishing Machinery Corp.*, 2530 Winthrop Ave., Indianapolis 5. Provision is made for holding ring sections to very accurate diameter during the deburring operation by interchangeable holding fixtures for different diameters of work pieces. Modifications of this design can be readily adapted for deburring other circular work pieces.

The experience of an aircraft engine company using the machine indicates a complete time cycle of 1 min. for loading, deburring and unloading a pair of 32-in. dia aluminum half rings. Previous hand methods of deburring required an 8-hour day for a set of 24 half rings. This machine is said to do the job in 12 min.

New Cleaning Method Utilizes Ultrasonic Waves

The Detrex Corp., Detroit, has announced the development of a practical method of metal cleaning through the use of ultrasonic waves. The new method, Detrex Soniclean Process, features a man-made element for directing sound energy—a development which company technicians say opens the door to far-reaching advances in a wide variety of industrial fields.

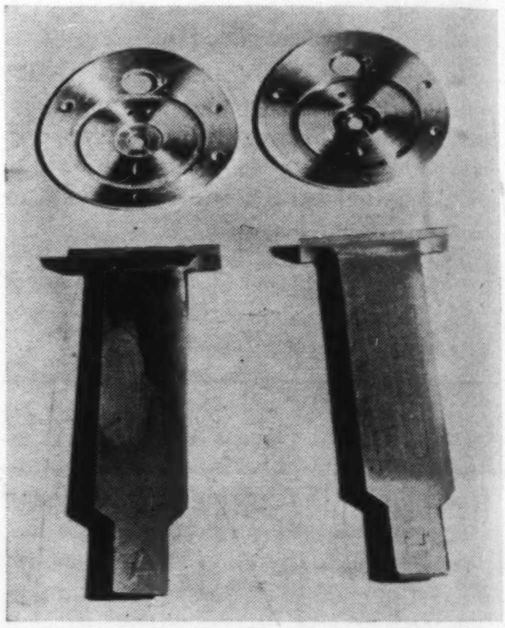
Foreign matter adhering to surface of this jet engine blade is almost exploded away by ultrasonic waves.

The element, jointly engineered by Detrex and Brush Electronic Co., is a curved piece of ceramic resembling a 6-in. long pipe, cut in half along the longitudinal axis. The ceramic pieces, which can be connected in series and arranged as desired, are designed to offer focusing and flexibility properties.

In the process, electrical energy is transmitted to the ceramic transducer, converted into sound energy, and projected through a solvent at a frequency of 430,000 cycles per sec. The solvent currently being used by the company is trichlorethylene; however, the process is not limited entirely to this material. Because a potential of only 40 v is required to operate the ceramic transducers, they can be safely immersed directly in the solvent. This eliminates the complicated sealed containers that are required with other transducer materials and high voltages.

Material to be cleaned is placed in the solvent, either manually or by conveyor, directly in the path of greatest focal intensity of the ultrasonic waves. In this area an extreme turbulence is created, resulting in a deep and penetrating cleaning action that is claimed to remove almost instantaneously all dirt, grease, chips and microscopic particles of soil from even the most intricately designed and close-fitting parts.

It was pointed out that because of the design of the ceramic transducer, the sound waves converge to a straight line as long as the transducer itself. The focal area in other transducers is confined to a single point. This restriction had limited ultrasonic cleaning almost to a one-at-a-time rate.



Metal parts before and after degreasing by ultrasonic waves are shown here.

In cases where exceptional cleaning quality is required, or where parts have fine openings, crevices and other hard to clean forms, the new process is fast and economical.

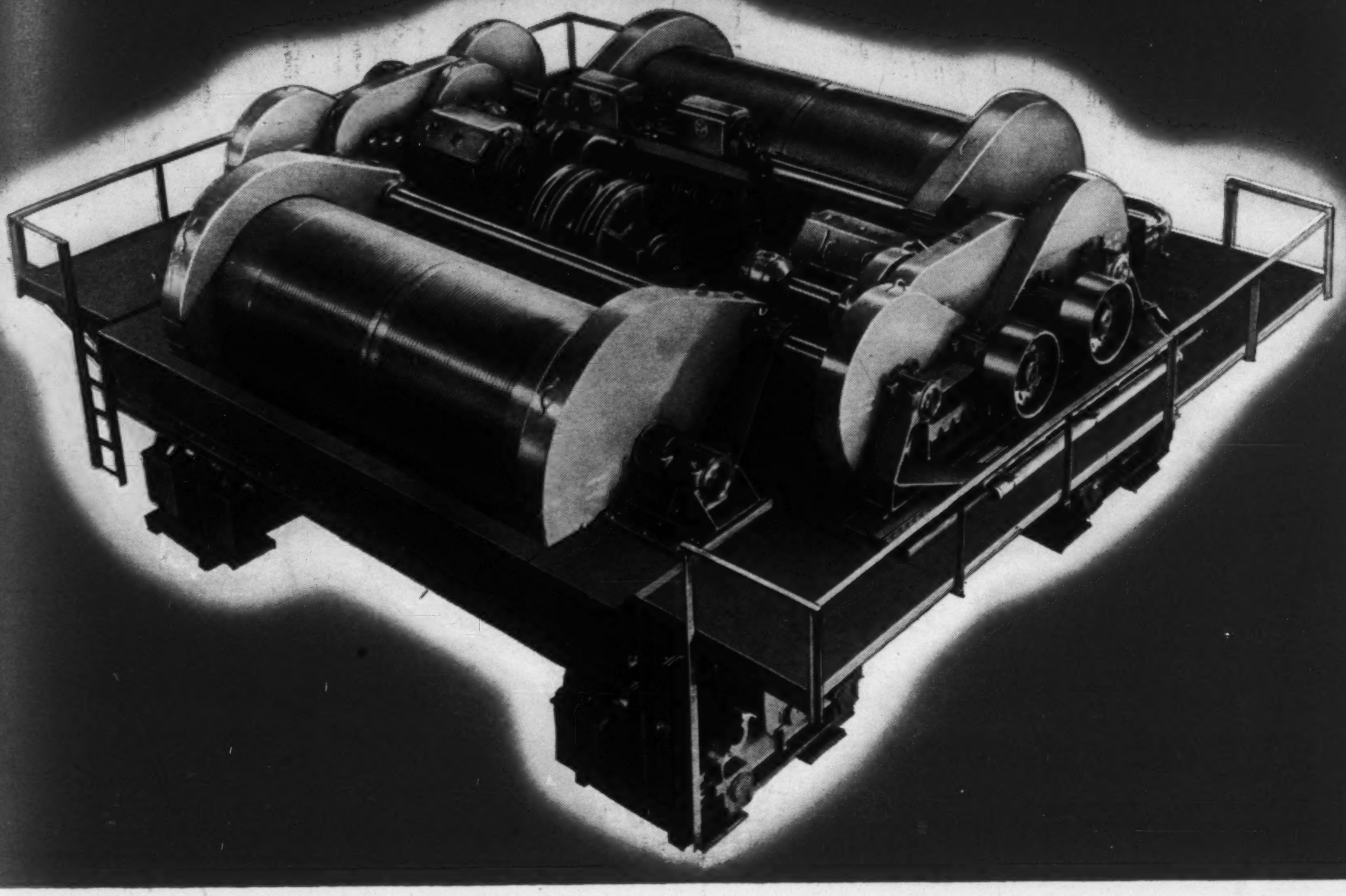
New Electrode Proves Successful in Many Applications

Metal and Thermit Corp., 100 E. 42nd St., New York 17, has announced a new and improved grade E-6010 electrode. According to the company, Murex Type R electrode has been tried with good results on such applications as: power piping, barge and tug boat construction, general fabrication of tanks and cylinders of various plate thicknesses, oil pipe lines, general shop welding and repair work.

Outstanding features of the electrode include: small amount of spatter, uniformity of arc behavior, lack of spearing, ability to take high currents without coating breakdown or change of performance as electrode is consumed, penetration without undercutting, and lack of reaction pitting when using whip technique.

(More News on page 146)

Reliability *PROVED* by MEEHANITE Cable Drums



HERE is another example of the rapid growth of engineering understanding of the reliability of Meehanite metal in component applications once believed beyond the possibilities of iron castings.

Illustrated is the main trolley for a 250 ton capacity crane built with Meehanite cable drums. The 4 drums required each weighed 14,500 lb., were 8 feet 4 inches long,—had a diameter of 62 inches. Such drums are not an experiment, but are among hundreds of similar units used by the industry because they have established exceptional service records.

Their combination of high compressive strength, toughness, and wear resistance, offers maximum life for not only the drum but for the cable itself.

Such properties, combined so as to meet *your* needs can be "built-into" your component parts. They are the result of the rigid manufacturing controls used in the production of Meehanite castings. Check your needs with your Meehanite foundry FIRST!

MEEHANITE®

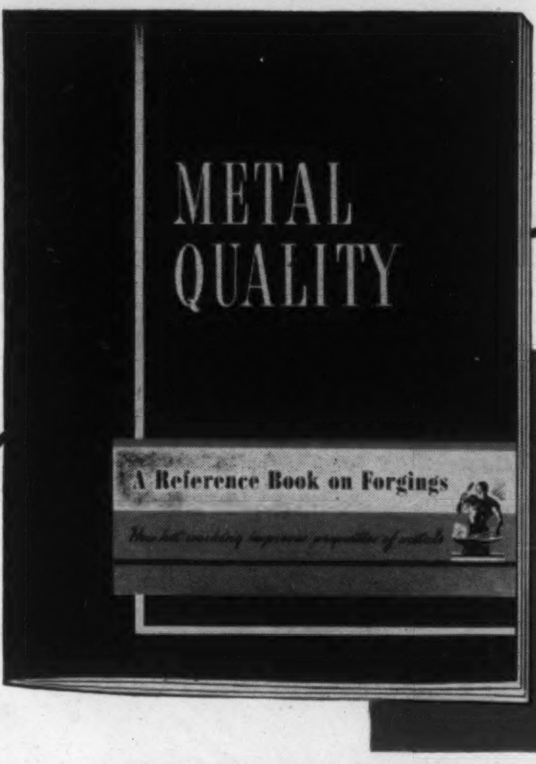
NEW ROCHELLE, NEW YORK

MEEHANITE FOUNDRIES

American Brake Shoe Co.	Mahwah, New Jersey
The American Laundry Machinery Co.	Rochester, New York
Atlas Foundry Co.	Detroit, Michigan
Banner Iron Works	St. Louis, Missouri
Barnett Foundry & Machine Co.	Irvington and Dover, New Jersey
E. W. Bliss Co.	Hastings, Mich. and Toledo, O.
Builders Iron Foundry	Providence, Rhode Island
Compton Foundry	Compton, Calif.
Continental Gin Co.	Birmingham, Alabama
Crawford & Doherty Foundry Co.	Portland, Oregon
The Cooper-Bessemer Corp.	Mt. Vernon, Ohio and Grove City, Pa.
De Laval Steam Turbine Co.	Trenton, New Jersey
M. H. Detrick Co.	Newark, N. J. and Peoria, Ill.
Empire Pattern & Foundry Co.	Tulsa, Oklahoma
Farrel-Birmingham Co., Inc.	Ansonia, Connecticut
Florence Pipe Foundry & Machine Co.	Florence, New Jersey
Fulton Foundry & Machine Co., Inc.	Cleveland, Ohio
General Foundry & Manufacturing Co.	Flint, Michigan
Greenlee Foundry Co.	Chicago, Illinois
The Hamilton Foundry & Machine Co.	Hamilton, Ohio
Hardinge Company, Inc.	New York, New York
Hardinge Manufacturing Co.	York, Pennsylvania
Johnstone Foundries, Inc.	Grove City, Pennsylvania
Kanawha Manufacturing Co.	Charleston, West Virginia
Koehring Co.	Milwaukee, Wisconsin
Lincoln Foundry Corp.	Los Angeles, California
London Concrete Company, Ltd.	Brantford, Ontario
E. Long Ltd.	Orillia, Ontario
Otis Elevator Co., Ltd.	Hamilton, Ontario
Palmyra Foundry Co., Inc.	Palmyra, New Jersey
The Henry Perkins Co.	Bridgewater, Massachusetts
Pohlman Foundry Co., Inc.	Buffalo, New York
Rosedale Foundry & Machine Co.	Pittsburgh, Pennsylvania
Ross-Meehan Foundries	Chattanooga, Tennessee
Shenango-Penn Mold Co.	Dover, Ohio
Sonith Industries, Inc.	Indianapolis, Ind.
Standard Foundry Co.	Worcester, Massachusetts
The Stearns-Roger Manufacturing Co.	Denver, Colorado
Traylor Engineering & Mfg. Co.	Allentown, Pennsylvania
Valley Iron Works, Inc.	St. Paul, Minnesota
Warren Foundry & Pipe Corporation	Phillipsburg, New Jersey

"This advertisement sponsored by foundries listed above."

MEEHANITE MEANS BETTER CASTINGS


METAL QUALITY
A Reference Book on Forgings
How hot working improves properties of metals

Engineering, production and economic advantages obtainable with forgings are presented in this Reference Book on forgings. Write for a copy.

FORGINGS ARE UNUSUALLY EFFECTIVE FOR SOLVING PROBLEM PART PROBLEMS

A problem part problem, however complex, often ceases to be a problem once all the aspects of the part are checked with the unrivaled economic and mechanical advantages of closed die forgings and the closed die forging process for producing parts. Whatever the nature of problems that make a problem part, consult a forging engineer to determine the extent to which forgings can help you solve them.

DROP FORGING ASSOCIATION
605 HANNA BLDG. • CLEVELAND 15, OHIO

Please send 60-page booklet entitled "Metal Quality—How Hot Working Improves Properties of Metal", 1949 Edition.

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Position ....

Company ....

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New Materials and Equipment

Fiberglass Reinforced Polyester Sheets Combine Useful Properties

Fiberglass reinforced polyester sheets are currently available in sizes up to 4½ by 8½ ft. and in a variety of thicknesses from *Strick Co.*, Plastics Div., Whitaker & Godfrey Aves., Philadelphia 24. The sheets are made in two grades: Grade I—20,000 psi; Grade II—40,000 psi. Both grades are said to have excellent resistance to a great variety of chemicals, which make them ideal materials for structural elements in corrosive atmospheres or baths.

The materials also exhibit high arc resistance and low power factor, making them suitable for use in the electrical and electronic industries. Formulated in varying degrees of flexibility, the materials can be molded to special shapes in lost cost tooling.

Phosphatizing Material Bonds Paint to Metal

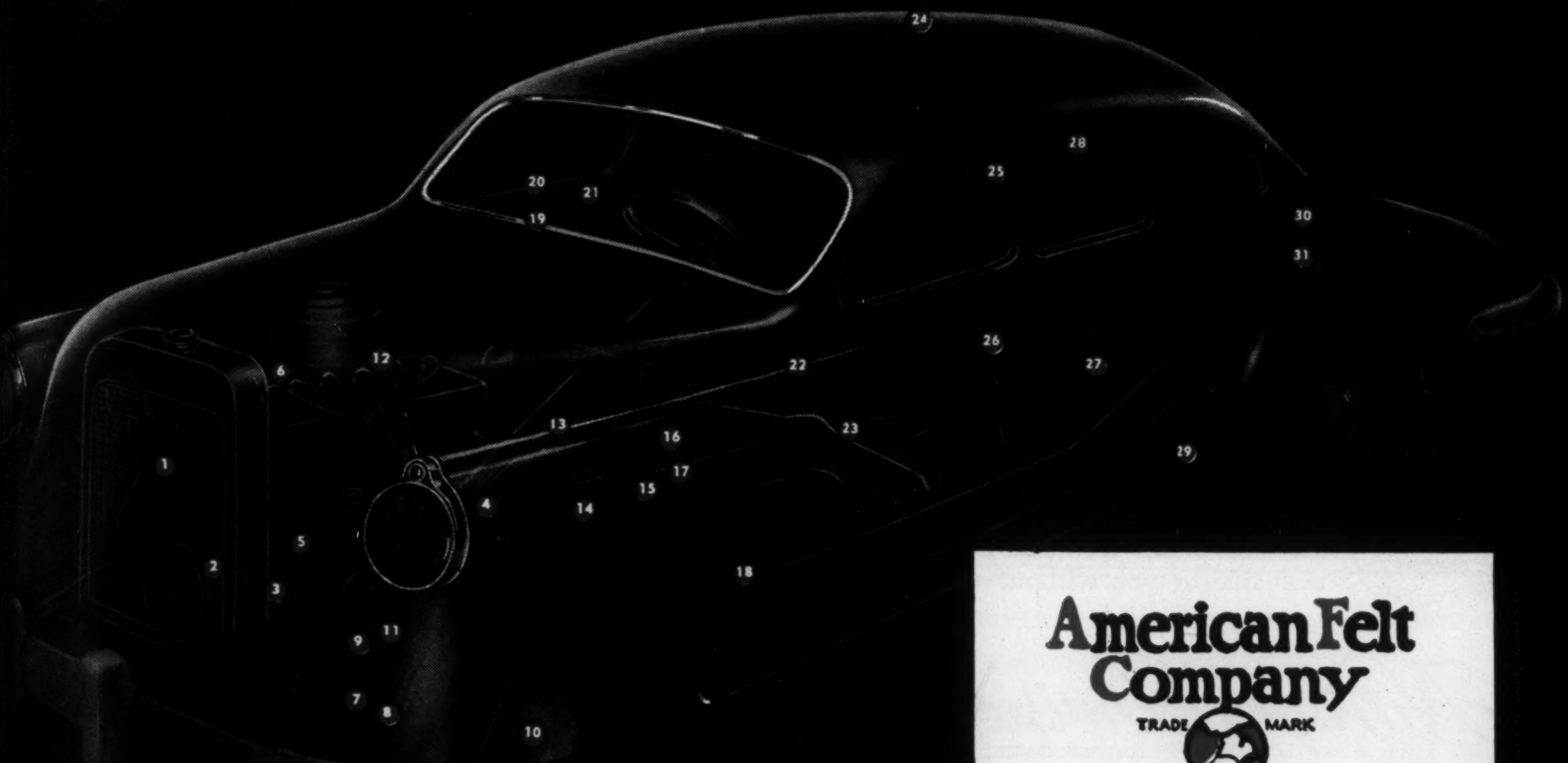
Development of a phosphatizing material which is said to create a complex zinc phosphate coating on steel and iron to promote excellent adhesion of paint to metal, has been announced by *Oakite Products, Inc.*, 157 Rector St., New York 6.

Oakite CrysCoat HC is claimed to provide a coating that is crystalline in nature and has a weight ranging from 200 to 1200 milligrams per sq ft, depending upon how it is applied and the type of

FELT IS USED IN EVERY CAR ...IN EVERY AUTOMOBILE FACTORY

Lubrication — Sealing — Insulating — Cushioning — Anti-Rattle
Anti-Squeak — Sound Absorption — Polishing — Silencing — Washers
Gaskets — Liners — Channels — Weatherstrip — Packing — Filtration

1 FAN BEARING OILER. 2 WATER PUMP PACKING AND OILER. 3 GENERATOR BEARING SEALS. 4 GENERATOR AND STARTER LUBRICATING WICKS. 5 OIL FILTER 6 BATTERY POSITIVE TERMINAL ANTI-CORROSION WASHER. 7 BRAKE BOLT OILER. 8 STEERING KNUCKLE TO TIE ROD DUST SEAL AND FLANGE JOINT SEAL. 9 STEERING ARM BEARING OILER. 10 FRONT WHEEL BEARING SEAL. 11 WHEEL BRAKE SHOE OILER. 12 CARBURETOR. 13 STEERING COLUMN GROMMET. 14 TRANSMISSION OIL SEAL WASHER. (SEAL ASSEMBLY TRANSMISSION BEARING) 15 DRIVE SHAFT DUST SEAL. 16 TOE BOARD AND FLOOR BOARD LINER. 17 CLUTCH HOUSING PAN DUST SEAL. 18 BODY TO CHASSIS STRIPS. 19 WINDSHIELD WIPER PIVOT ARM MOUNTING. 20 WINDOW LIFT LUBRICATORS. 21 DOOR PANEL INSULATOR. 22 FLOOR BOARD PARTS. 23 UNIVERSAL OIL SEAL. 24 TURRET TOP INSULATION. 25 WINDOW RUN CHANNEL. 26 REAR AXLE DRIVE SHAFT SEAL. 27 AXLE PINION DRIVE BEARING SEAL. 28 UPHOLSTERY RISER STRIPS 29 SPRING COVER LINING. 30 REAR PANEL WEATHERSTRIP. 31 FUEL TANK STRAP GASKET.



American Felt Company
TRADE MARK

GENERAL OFFICE: GLENVILLE, CONN.
Engineering and Research Laboratories: Glenville, Conn. PLANTS: Glenville, Conn.; Franklin, Mass.; Newburgh, N. Y.; Detroit, Mich.; Westerly, R. I.
SALES OFFICES: New York, Boston, Chicago, Detroit, Cleveland, Rochester, Philadelphia, St. Louis, Atlanta, Dallas, San Francisco, Los Angeles, Portland, Seattle, Montreal.

Write for S.A.E. Data Sheet No. 5, containing samples and full specifications of the standard S.A.E. Felts.

Some Additional Applications of Felt: Clutch release link lever oiler • Window anti-squeak • Fuel tank support lining • Brake shoe anchor pin washer • Drag link dust cover • Intermediate steering arm bearing seal • Windshield wiper motor washer • Toe and floor board anti-squeak • Solenoid cover gasket • Heater core to housing filler • Spindle bolt grease retainer • Spindle bolt dust washers • Radius rod felt • Hydraulic lift spring seat • Door bumpers • Pedal pads and seals • Dash liners • Oil retainers • Polishing felts, for glass, metal and paint • Door liners • Ventilator valve seals • Weather seals • Hood lace filler • Moulding shim • Timing gear cover pad • Accelerator rod pad • Fuel tank shim • Propeller shaft spline oiler • Paint filter bags • Crankcase oil filter cap • Brake dirt seals • Defroster control valve seal • Hand brake cable clamp seal • Windshield division filler • Pinion bearing retainer packing • Horn wire locator felt • Oil sabre dust washer • Fender welt felt • Spring oiler felt • Spring bumpers • Gas filling protector pads • Rocker arm seals • Chafing strips for convertible tops • Upholstery padding • Radio selector pads • Thrust bearing inserts • Cab roof lining • Antenna weather seal • Blankets for protection during assembly and service • Factory table pads • Glycerine pads for windshield wipers •

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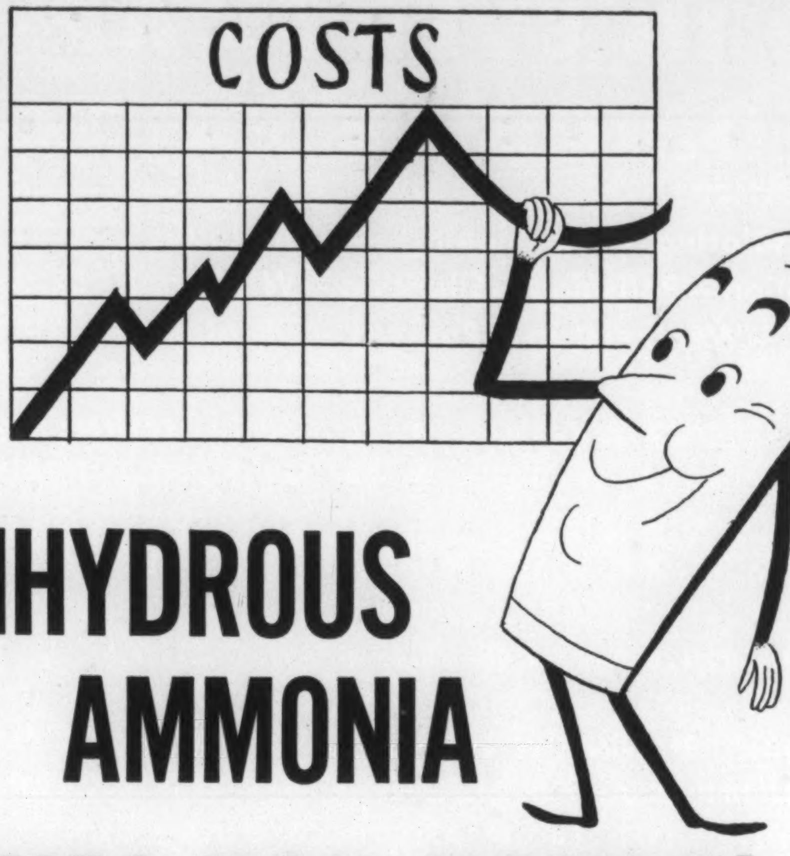

ANHYDROUS AMMONIA

SAVES YOU MONEY!

Barrett® Brand Anhydrous Ammonia is one of the most economical sources of hydrogen and nitrogen for metallurgical uses.

When partially dissociated, Anhydrous Ammonia is used in the nitriding of alloy steels and in carbonitriding for treatment of steel. Carbonitriding, often referred to as "Dry Cyaniding," has in many instances replaced the liquid cyanide bath to economically produce cases on low carbon steels.

Dissociated, or "cracked," ammonia is used as a protective atmosphere for bright annealing, brazing and powder metallurgy. It is also used as hydrogen for welding, for descaling metals by the sodium hydride process, and as an economical source of hydrogen in electronics. In addition, it is used in the hydrogenation of fats and oils.

NITROGEN DIVISION ALLIED CHEMICAL

Write for full information on how Barrett® Brand Anhydrous Ammonia can save you money. The advice and help of our technical men are available to you without charge.

Nitrogen Division
ALLIED CHEMICAL & DYE CORPORATION
40 RECTOR STREET • NEW YORK 6, N. Y.

Mail Coupon for your free copy of this new booklet. Helpful, informative, contains latest data on the use of Anhydrous Ammonia.

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Please send me a copy of your new booklet, "Guide for the Use of Barrett® Brand Anhydrous Ammonia in Cylinders."

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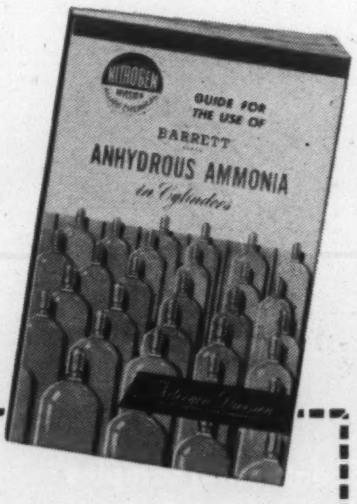

New Materials and Equipment

steel being treated. It can be used in tanks and in pressure-spray washing machines, and with both methods the following Government Specifications are fully met: JAN-C-490, Grade I; 57-O-2C, Type 2, Class C; and PA-PD-191 Rev. A. According to the company, the salt spray resistance of painted parts treated with the material exceeds the requirements of these Specifications.

Outstanding advantages claimed for the material are: sludging and scaling are held to the absolute minimum; an all stainless steel tank set-up is not necessary—the tank can be of stainless steel, if available, but mild steel is satisfactory; the material is simple to use, only one material being involved. No special additives or toners are needed, and upkeep is determined by a simple titration procedure, with the equipment for this being supplied by the manufacturers.

Polyester Resin Liquid Does Not Run

A new polyester resin which will not drain even from smooth vertical surfaces has been developed by *Marco Chemicals Inc.,* 1711 Elizabeth Ave. West, Linden, N. J. Designated as Marcothix Resin #1, it is said to completely overcome the drainage problem, which has long been considered the most serious drawback in producing molded laminates such as boat hulls, auto bodies, aircraft parts, tanks, etc. by hand lay-up procedures. It greatly simplifies application of protective coatings to storage tanks, cinder block, concrete and various contoured objects.

Easily applied by brush or spray, the resin will stay put even at substantially elevated temperatures. It is said to be truly thixotropic — its viscosity being a function of the shearing force applied. When not disturbed, it maintains its shape like a lubricating grease; yet when shaken in a container, it will splash like a liquid of only moderate viscosity.

Translucent and pale buff in color, Marcothix Resin #1 can be cured in the same manner as ordinary liquid polyesters —either at elevated or room temperature through the use of the proper catalyst and Marco accelerator.

Another valuable feature claimed for the resin is its ability to hold reinforcing cloth or mat in close contact with the mold surfaces or other plies of the same laminate—even around sharp bends such

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TURBO-COMPRESSOR
Data Book
NO. 107-C
SPENCER

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If you need air for heat treating, or large volumes of air for cooling, drying, or chemical agitation, you need these two new Spencer Data Books.

No. 107-C The Turbo Compressor Data Book gives a wealth of experience in pneumatic engineering, including orifice equivalents, equalization of pipes, effect of pressures and altitudes and friction losses.

No. 126-A describes the Spencer Turbo-Compressor, lists more than 160 standard capacities from 1/3 h.p. up, including electric, gas engine, turbine and belt driven units.

With these books, you can apply Spencer Turbos to any of the more than twenty industrial uses illustrated and described. Much of this information is new. Ask for your copies now.

440-A

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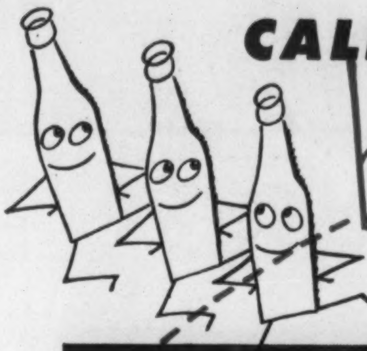
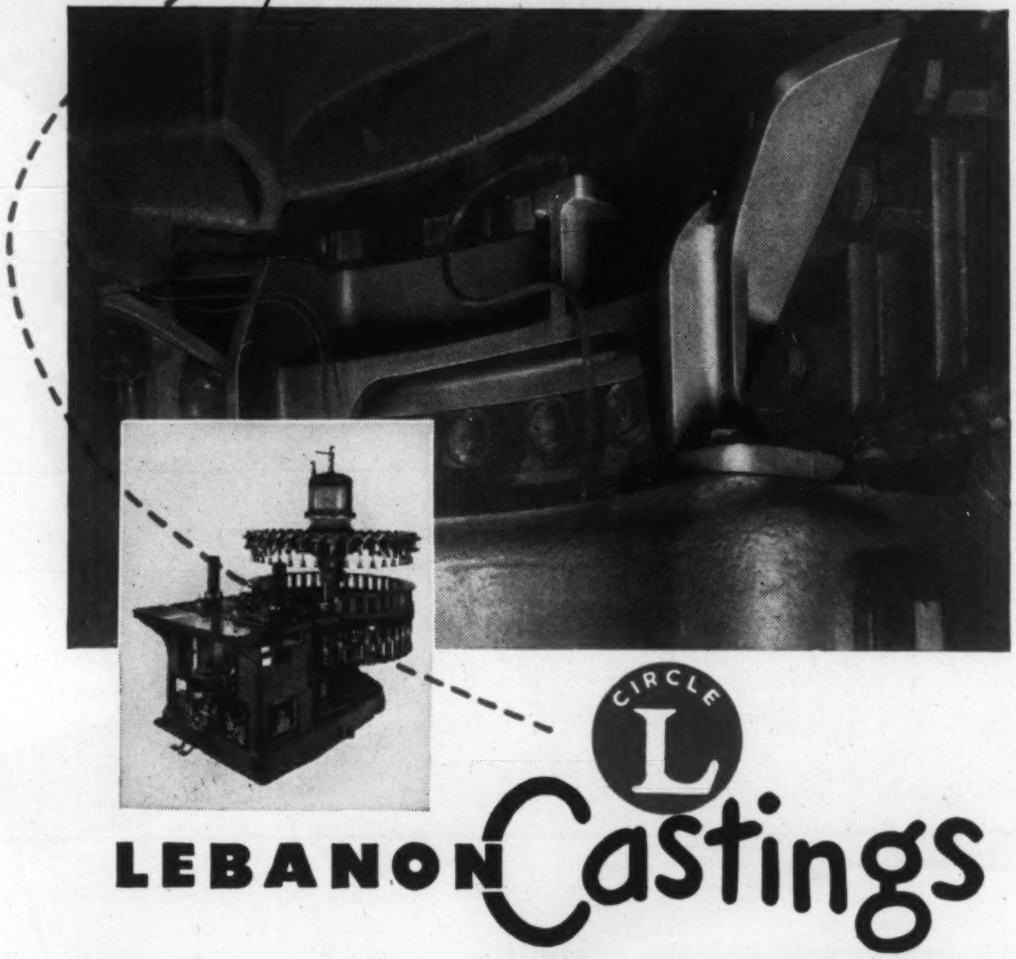




CALLING A FIGURE IN A bottle dance

LEBANON CIRCLE L Castings ARE AT WORK

EVERYONE is fascinated by the sound and action of modern bottling machinery at work. It's the cams that "call the figures in this bottle dance"! And these cams have to be tough.

In Crown Cork & Seal Company's CEM 40 bottling machine, illustrated above, the sturdy cam is a Lebanon CIRCLE Ⓛ special alloy steel casting. The efficiency of this machine that fills and caps many millions of soft drink bottles a year, is due in part, to the special wear and endurance properties built into the Lebanon Alloy Steel employed in casting the cam. The cam illustrated must hold its form and size, must keep wear to a minimum thereby eliminating expensive machine down-time.

Wherever castings are required, it's sound practice to use only the highest quality. Those bearing the CIRCLE Ⓛ trade mark are high quality products of true Lebanon craftsmanship.

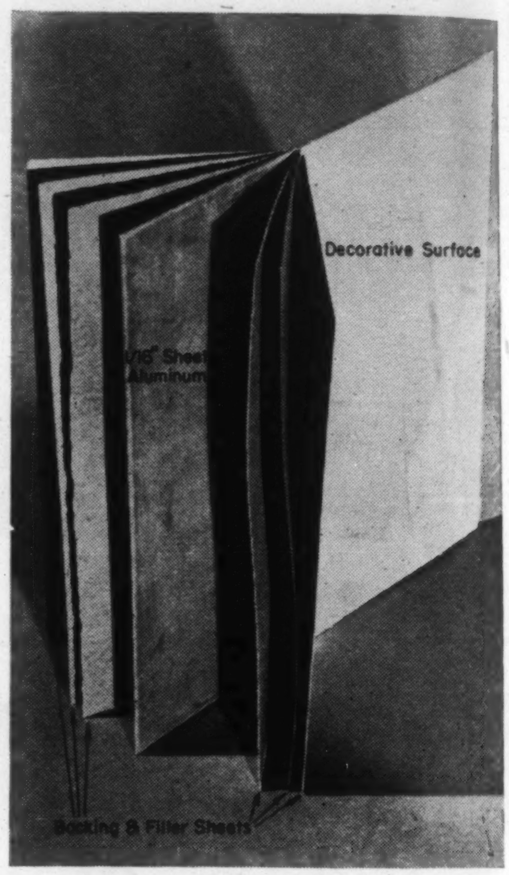
You should see . . .
STEEL WITH A THOUSAND QUALITIES

This 37 min., 16 mm. full color sound film showing the making of steel castings from blueprint to end use should be shown to your staff. For information write: Dept. D, Lebanon Steel Foundry, Lebanon, Pa.

LEBANON Castings CIRCLE L
CARBON, SPECIAL ALLOY AND STAINLESS STEEL
LEBANON STEEL FOUNDRY LEBANON, PA.

New Materials and Equipment

as reinforcing ribs. According to the company, the cured resin provides excellent chemical, moisture and abrasion resistance and has outstanding electrical properties.



Fireproof Micarta Plastic Now Available

A fireproof, decorated Micarta plastic is now available from *Westinghouse Electric Corp.*, P. O. Box 2099, Pittsburgh 30. This grade of Micarta makes all types of decorator combinations possible in office and other public buildings where safety is a major factor in construction.

The new material is formed in a single process by sandwiching a 1/16-in. aluminum sheet between layers of melamine plastic. The bond between the aluminum and plastic is so strong that it can be subjected to widely fluctuating extremes of temperature as well as humidities up to 100%, without breaking.

The safety of the new plastic from a fire-repellent standpoint comes from the heat-conducting aluminum and the melamine coating. The foundation aluminum sheet disperses heat that may be caused by such things as hot food containers, cigarettes, or accidental fires that occur in any kind of building. The melamine outer

Better Product Design
4 WAYS
with Control-Free Tin-Zinc Plating

1 *Protection-wise . . .*
Tin-zinc plate provides excellent corrosion resistance. It is less porous than pure tin—and outperforms zinc or cadmium in many environments.

2 *Application-wise . . .*
Tin-zinc plate possesses permanently outstanding soldering characteristics . . . of value to the electronics industry. It is well suited also for malleable iron castings . . . and for recessed parts of steel, brass, copper and other base metals where it provides a smooth finish and uniform corrosion resistance throughout.

3 *Economy-wise . . .*
Tin-zinc plating uses 20% less tin than electrotinning and approximately 60% less tin than hot dipping. Metal cost is not much more than half that of cadmium.

4 *Production-wise . . .*
The tin-zinc plating process is easily controlled. Areas ordinarily difficult to plate with other finishes are no problem with tin-zinc because the tin-zinc bath has throwing power unsurpassed by any other plating solution.

FULL DETAILS ARE YOURS—Technical Data Sheet No. 107 gives complete information on the tin-zinc plating process, which is now free of government restrictions. Write for information now—and include any questions you'd like answered.

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METALS and ALLOYS
ARC WELDING—Materials and Equipment
CHEMICALS and ANODES for Electrotinning
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TIN, ANTIMONY and ZIRCONIUM CHEMICALS

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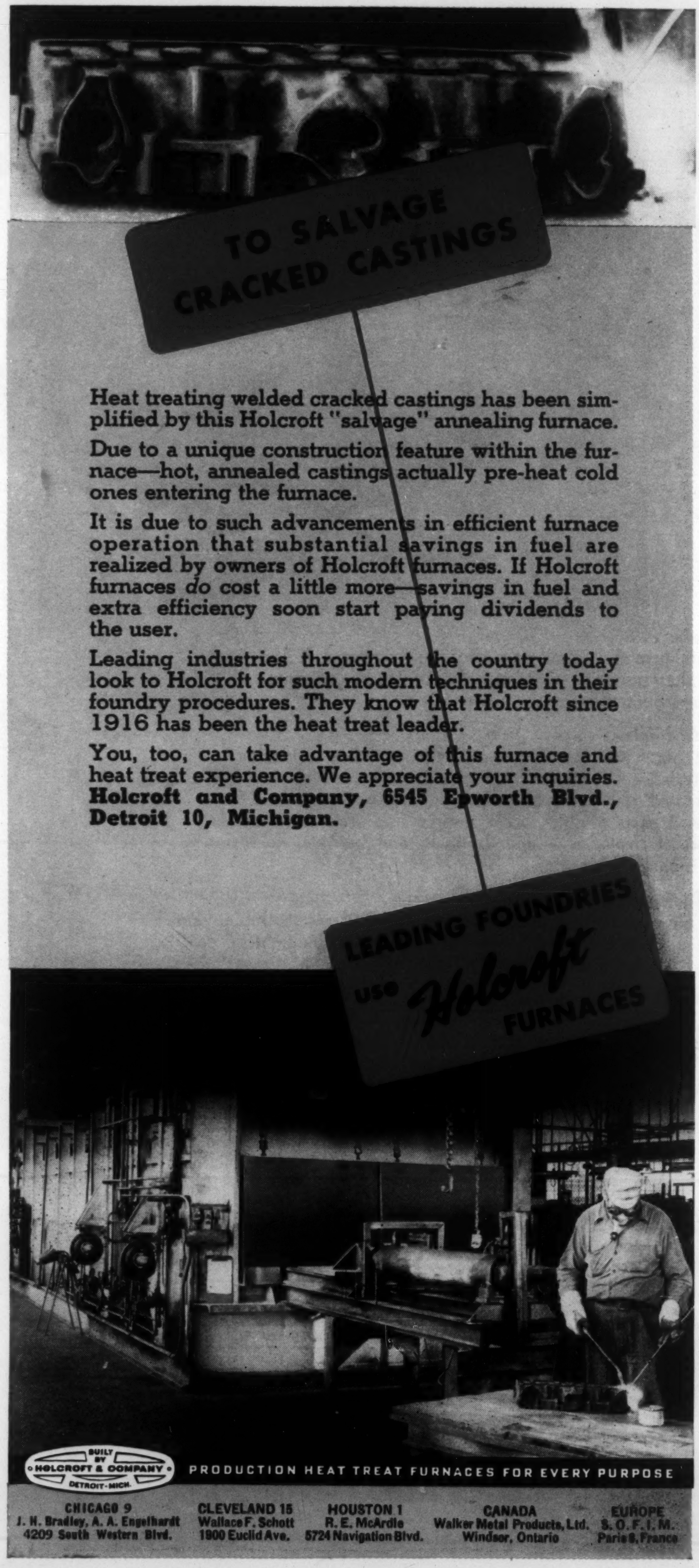


TO SALVAGE CRACKED CASTINGS
LEADING FOUNDRIES use Holcroft FURNACES

Heat treating welded cracked castings has been simplified by this Holcroft "salvage" annealing furnace.

Due to a unique construction feature within the furnace—hot, annealed castings actually pre-heat cold ones entering the furnace.

It is due to such advancements in efficient furnace operation that substantial savings in fuel are realized by owners of Holcroft furnaces. If Holcroft furnaces *do* cost a little more—savings in fuel and extra efficiency soon start paying dividends to the user.

Leading industries throughout the country today look to Holcroft for such modern techniques in their foundry procedures. They know that Holcroft since 1916 has been the heat treat leader.

You, too, can take advantage of this furnace and heat treat experience. We appreciate your inquiries. Holcroft and Company, 6545 Epworth Blvd., Detroit 10, Michigan.

BUILT BY HOLCROFT & COMPANY DETROIT-MICH.

PRODUCTION HEAT TREAT FURNACES FOR EVERY PURPOSE

CHICAGO 9	CLEVELAND 15	HOUSTON 1	CANADA	EUROPE
J. H. Bradley, A. A. Engelhardt 4209 South Western Blvd.	Wallace F. Schott 1900 Euclid Ave.	R. E. McArdle 5724 Navigation Blvd.	Walker Metal Products, Ltd. Windsor, Ontario	S. O. F. I. M. Paris 8, France

New Materials and Equipment

layer does not sustain combustion, though it will char after heat has been applied for an appreciable length of time.

The material can be supplied in a wide variety of colors and woodgrain or textile finishes.

Anodizing Process Gives Corrosion and Abrasion Resistant Film

A new anodizing process, said to give a superior corrosion and abrasion resistant film to the surface of aluminum and its alloys, has been announced by *Philton Co.*, 200 W. Ninth St., Wilmington, Del. Known as Ec Electrodizing, the process can be controlled to meet required specifications. It is said to provide a protective surface at a fraction of the cost of conventional sulfuric acid and chromic acid processes. Power cost alone is claimed to be one-fifth or less that of comparable results to meet Army, Navy and Air Force specifications.

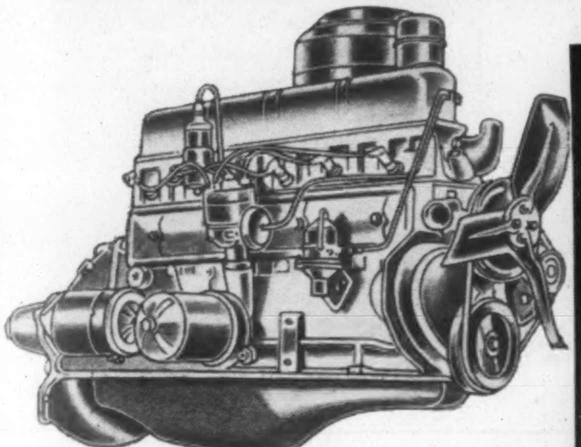
In the process, which uses properly balanced electrolytes, a relatively porous film is generated first. Through this film, a relatively nonporous film is induced directly on to the surface of the metal being treated. The process combines the advantages of the sulfuric and chromic acid processes and also is said to compensate for their disadvantages.

In addition to power savings, economic advantages are claimed to accrue from: decreased cost of electrolyte; completion of 4 to 5 times as much work with the same equipment; reduction of down time and dumping practically to zero; about 50% reduction in tooling cost; and negligible cost of heat sealing.

Electrode for Rebuilding Steel Parts

While there are many electrodes on the market which are variously recommended as suitable for general welding and build-up, many of them do not supply all the properties required for rebuilding of steel parts preparatory to a hard-facing overlay, according to *Stoody Co.*, Whittier, Calif. A new electrode recently marketed under the name Stoody Build-Up by that company, has been developed with the idea of providing the properties necessary in a

5 PANGBORN SPECIAL ROTOBLASTS Do TOP QUALITY Job for FORD



Clean 80 tons of castings an hour at the Ford Cleveland Foundry

At no point are Ford's quality requirements more exacting than at its new Cleveland foundry—production show-place of the Ford Motor Company. That's why it's important that Ford chose Pangborn Special ROTOBLAST® Cleaning Machines to handle the major part of this foundry's blast cleaning. The total output of these five monorail machines will be 80 tons of castings cleaned per hour.

Ford picked Pangborn because parts must be cleaned *perfectly,* even beyond the demands of adequate performance—and *quickly,* to keep pace with other production processes, to keep costs in line! Pangborn can give *you* the same better, faster, cheaper performance. If you have *any* blast cleaning problem, write today for Bulletin 214. Write to: PANGBORN CORPORATION, 1700 Pangborn Boulevard, Hagerstown, Maryland.

Pangborn Machine #2 cleaning cylinder blocks. Worker at right transfers castings from grinder to station where two workers in center foreground load them on conveyor hooks for cleaning.

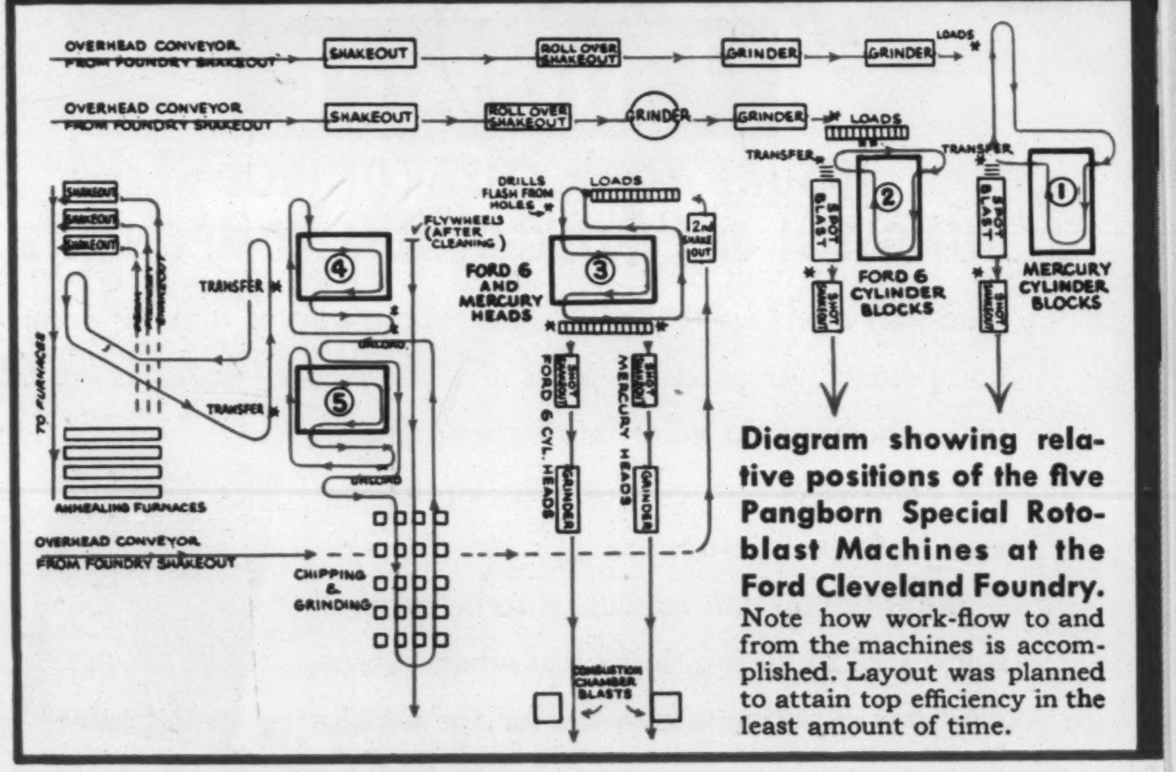

OVERHEAD CONVEYOR FROM FOUNDRY SHAKEOUT
SHAKEOUT
ROLL OVER SHAKEOUT
GRINDER
GRINDER
LOADS
OVERHEAD CONVEYOR FROM FOUNDRY SHAKEOUT
SHAKEOUT
ROLL OVER SHAKEOUT
GRINDER
GRINDER
LOADS
TRANSFER
TRANSFER
SHOT BLAST
②
SHOT BLAST
①
SHOT SHAKEOUT
FORD 6 CYLINDER BLOCKS
SHOT SHAKEOUT
MERCURY CYLINDER BLOCKS
SHAKEOUT
SHAKEOUT
SHAKEOUT
TO FURNACES
TRANSFER
④
TRANSFER
⑤
UNLOAD
UNLOAD
ANNEALING FURNACES
FLYWHEELS (AFTER CLEANING)
DRILLS FLASH FROM HOLES
LOADS
③
2nd SHAKE OUT
FORD 6 AND MERCURY HEADS
SHOT SHAKEOUT
FORD 6 CYL. HEADS
GRINDER
SHOT SHAKEOUT
MERCURY HEADS
GRINDER
OVERHEAD CONVEYOR FROM FOUNDRY SHAKEOUT
CHIPPING & GRINDING
COMBUSTION CHAMBER BLASTS

Diagram showing relative positions of the five Pangborn Special Rotoblast Machines at the Ford Cleveland Foundry. Note how work-flow to and from the machines is accomplished. Layout was planned to attain top efficiency in the least amount of time.

OVER 28,000 PANGBORN MACHINES SERVING INDUSTRY

Look to Pangborn for the latest developments in Blast Cleaning and Dust Control equipment

FOUNDRY EQUIPMENT MANUFACTURERS ASSOCIATION INC. MEMBER FEMA

Pangborn

BLAST CLEANS CHEAPER

with the right equipment for every job

Fansteel Fabrication of Tungsten & Molybdenum Components

means

- √ one responsibility
- √ one price
- √ one standard of quality

We MAKE both Tungsten and Molybdenum—from raw ore to finished ingot, bar, rod or sheet. You can *expect* us to know more about these metals—about forming them, about stamping, bending, deep drawing, machining, forging, brazing or welding them.

LET **Fansteel**

INSURE YOUR COST CONTROL of TUNGSTEN and MOLYBDENUM COMPONENTS

You can *expect* us to arrive at the best way of making your component, to produce it at the least cost—to guarantee you, when we do your fabrication, against the vagaries of rejects, scrap loss, equipment and personnel tie-up.

Bluntly, you can expect us to be experts. For, in all modesty, that's just what we are. And our experience is yours for the asking.

Write for Free Booklet!
"FANSTEEL TUNGSTEN AND MOLYBDENUM"

FANSTEEL
WORLD'S LARGEST PRODUCER OF REFRACTORY METALS

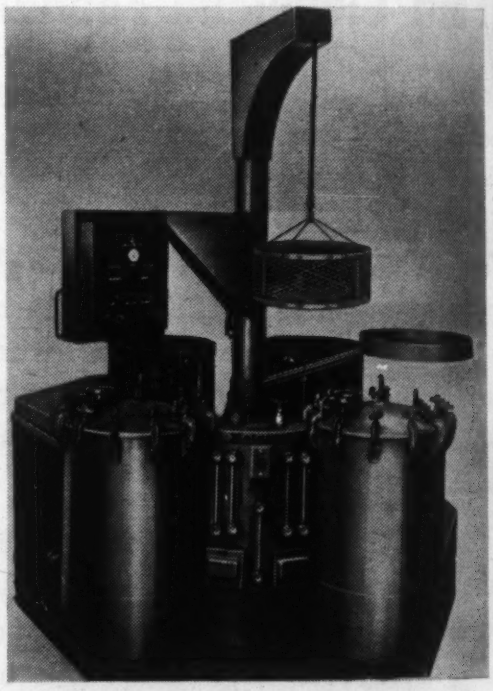
TUNGSTEN & MOLYBDENUM

32501C

Fansteel Metallurgical Corporation NORTH CHICAGO, ILLINOIS, U.S.A.

material used for rebuilding carbon steel and alloy steel parts—sound deposits, high tensile strength, toughness and resistance to cold flowing. As an underbase, it is generally recommended for such parts as drive sprockets, churn drills, shovel drive tumblers and house rolls, tractor rollers and idlers, tool joint shoulders and clutch jaws.

Stoody Build-Up is an extruded alloy-coated electrode designed to produce an alloy steel deposit of consistent medium hardness of 29-31 Rockwell C under normal conditions. Deposits are affected by heat treatment and will react to abnormal temperature ranges like any other alloy steel.



System for Mechanized Impregnation of Metal Castings

A new system that is said to accomplish foolproof and economical sealing of porous castings has been developed by *American Metaseal Manufacturing Corp,* 30 E. 60th St., New York 22. The heart of the new system is a self-contained unit comprising autoclaves, high-vacuum pump, thermostatically controlled wash tanks, a mechanical surging unit and a power operated hoist. This, in combination with the Metaseal 19V5 resin, is claimed to make possible for the first time 100% filling of micropores in metal castings with successful results.

The new machine is designed for simple one-man operation. It is built around a

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STEATITE • ZIRCONIUM OXIDE • ZIRCON
MAGNESIUM SILICATE • ALUMINUM SILICATE
FORSTERITE • TITANIUM DIOXIDE

VERSATILE

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BOOTH 71
Exposition of
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For Industry
GRAND CENTRAL PALACE
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JUNE 15-19, 1953

Development of new, special purpose ceramic compositions is a regular part of our work. No matter what your requirements are, the chances are good that we have an AlSiMag composition that will do the job.

If you need a material with special characteristics or have a difficult design involving intricate shapes or close tolerances, give us your requirements. Let us show you what we can do.

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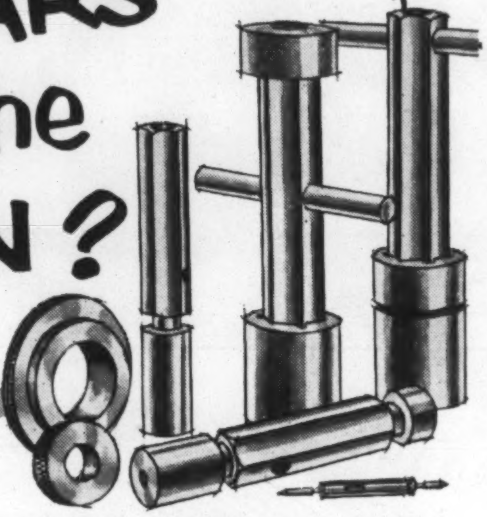
Are you throwing THOUSANDS OF DOLLARS into the SCRAP BIN?



You can now chrome plate worn gages *IN YOUR OWN SHOP*

This compact new chrome plating unit is saving real money for leading engineering and manufacturing concerns throughout the country. For instance, here's what Taller and Cooper, Inc., foremost makers of toll collection equipment and builders of electro-mechanical measuring and recording devices, say about their Chromaster installation:

"Within one hour from the time a space was arranged for the unit, the Chromaster was in operation. In the very first day over $100.00 worth of undersize plug gages that normally would have been discarded were replated and put back in use in our inspection department."

Same saving applies to other small tools

Normal life of your cutting tools and wear parts can be multiplied 3 to 10 times by this accurate, simplified method of chrome plating right in your own shop. Chromaster deposits chrome with positive uniformity yet the average job takes only 3½ minutes.

Chromaster

A Chromaster for every shop

Model A-20 (shown here) is a 20-amp, bench-mounted unit for the gage room or tool crib; plates up to 10 sq. in.

Model A-50, 50-amp, bench-mounted unit for larger shops in plating of cutting tools. Plates up to 25 sq. in.

Model A-250, 250-amp, floor-mounted unit for production plating of small parts in greater quantities or larger parts with areas up to 125 sq. in.

Chromaster

Write for cost-cutting free information today!

Industrial Chrome Division
Ward Leonard Electric Co.
16 South Street,
Mount Vernon, N. Y.

Please send me complete information on Chromaster industrial chrome plating

NAME..........
COMPANY..........
ADDRESS..........
CITY.......... ZONE.... STATE..........

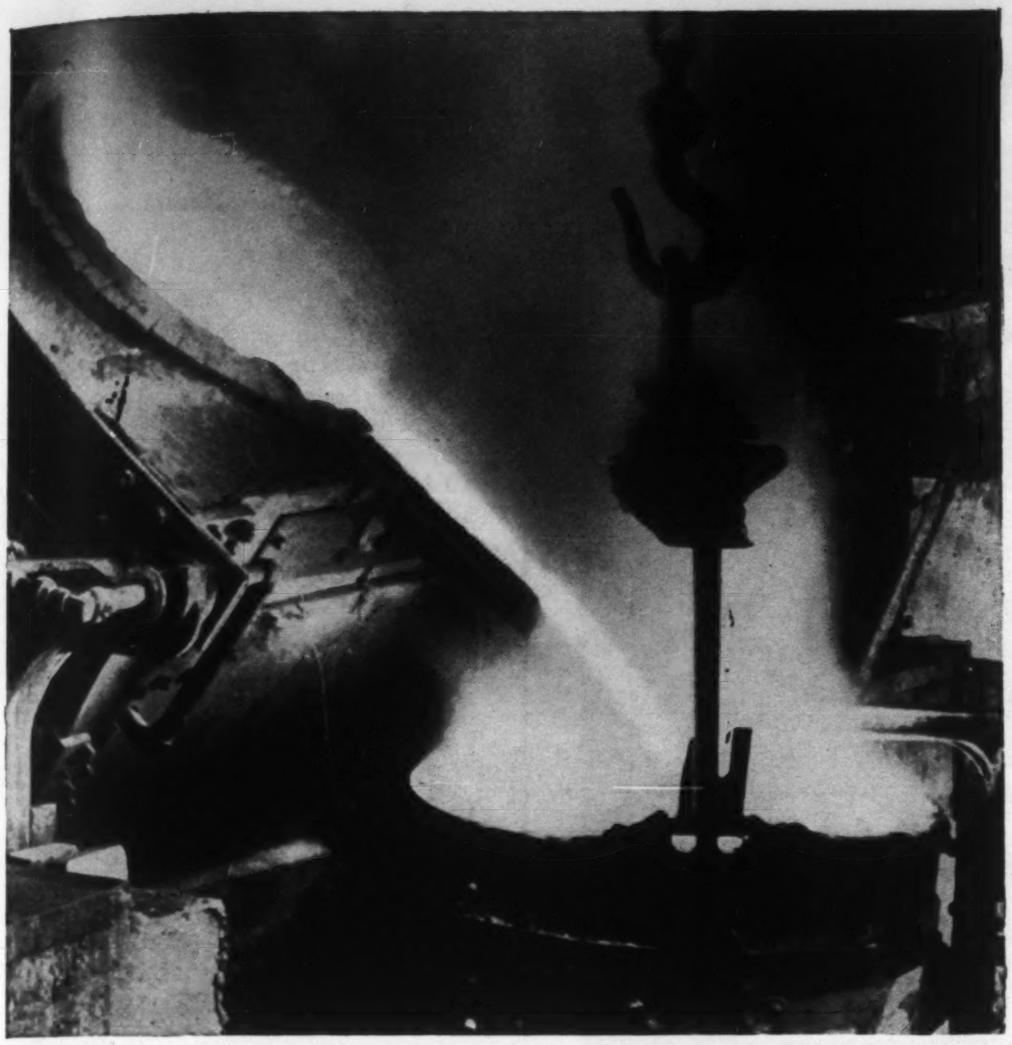
center hub unit which contains the activating hub cylinders; this hub unit mechanizes all functions of the machine, from basket loading through the vacuum-pressure cycle and the cleaning surge.

Metaseal 19V5 is a solventless type of impregnating compound. In the new method, the resin in monomer form (containing no solvents or other volatile matter) flows into the pores under vacuum, pressure filling them completely; the entire casting is heated and the resin polymerizes into a hard, infusible material. Besides its superiority to the solvent-type impregnants, the resin represents a basic improvement over other solventless impregnation processes, which utilize polyester-type resins. These materials require refrigeration, thus increasing their viscosity to a point where it interferes with rapid production—in addition, the viscosity is never constant. Metaseal 19V5 impregnant, however, does not require refrigeration, agitation or aeration; thus, the viscosity is maintained at the ideal value required for all types of castings, and this viscosity remains constant throughout the operation. Also, because of the excellent wetting properties of the resin, positive pore penetration is assured at all times. Another feature of the resin is that it is stable with all alloys, including copper-base materials; polymerization is not inhibited by any metals. The cured resin is resistant to a wide range of acids, alkalis, solvents and other chemicals. In addition to being an impregnant, Metaseal 19V5 is a good bonding agent and provides excellent corrosion resistance for all metals.

Because of the excellent sealing and corrosion resistant properties of the new process, it is applied naturally to any product that requires sealing against liquids and gases, as well as protection against corrosive agents. The process has been used successfully to impregnate both bronze and stainless steel chemical pump castings, and it is said to be especially effective in the impregnation of magnesium castings on an economical basis. Typical magnesium castings in which Metaseal has been applied include aircraft parts such as throttle bodies and housings.

Chilling Machine Reaches −140 F

Addition of a new standard model to its line of industrial chilling machines has been announced by *Sub-Zero Products Co.*, Reading Rd. at Paddock, Cincinnati 29.



50 TONS

of Stainless Steel a Day...

Melted in this AJAX-NORTHRUP INDUCTION FURNACE

Every 1¾ hours, one of these Ajax-Northrup furnaces pours 10,000 pounds of top-quality stainless steel. Total capacity is well over 50 tons a day!

Composition is uniformly exact. Alloying elements are controlled within a fraction of a per cent in every melt. Carbon is consistently kept below 0.05%.

Losses of expensive elements are negligible. Operating costs have been low enough to pay for the furnaces in just a few years!

This installation is typical of the growing use of induction melting for larger and larger jobs. In some of these, induction melting is the only way the job can be done. In others, it does the job better, faster, and at lower cost than any other melting method.

No matter what the job . . . or the quantity . . . Ajax-Northrup's 36 years of induction experience can help you. Just write or call us.

AJAX ELECTROTHERMIC CORPORATION
Ajax Park, Trenton 5, New Jersey

Associated Companies
AJAX ELECTROMETALLURGICAL CORP.
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AJAX ELECTRIC COMPANY, INC.
AJAX ENGINEERING CORPORATION

AJAX NORTHRUP
INDUCTION HEATING AND MELTING

Since 1916

148

Keep in Step with—
RIGID GOVERNMENT
TUBING REQUIREMENTS

SPECIFY "Standard"
for Welded Stainless Steel Tubing

The Heat Exchanger exemplifies one of the severest uses for stainless tubing. "Standard's" stainless tubing meets this, as well as many other different requirements for strength, and heat and corrosion resistance.

Deal with the Specialist among Specialists

A tubing specialist, like other specialists, knows his trade best.

When you deal with "Standard" you deal with a tubing specialist who manufactures millions of feet of tubing every month from stainless and carbon steel—and for 25 years has been serving all types of industry for mechanical and pressure tubing applications.

If you need stainless tubing, be sure you specify "Standard". It pays to deal with the tubing specialist among specialists.

Stainless Tubing Size and Thickness
3/8" O.D. to 3" O.D.
.028 to .095 wall
Carbon Steel Tubing
1/2" O.D. to 5 1/2" O.D.
.028 to .260 wall

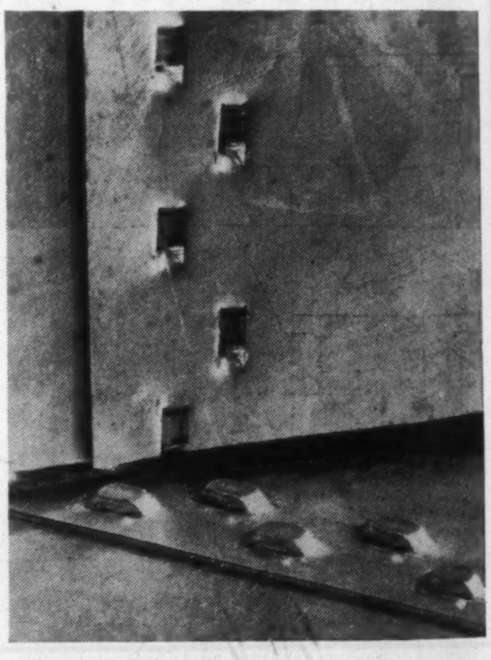
THE STANDARD TUBE CO.
Detroit 28, Michigan
Welded Tubing
Fabricated Parts
STANDARDIZE with STANDARD — It Pays

New Materials and Equipment

The new unit, Model T-120, is designed to provide chilling capacity down to 140 deg below zero F for moderate scale production needs. Thermal capacity of the unit will be 1200 Btu per hr at −120 F—enough to chill 50 lb of steel an hr from 80 F to −120 F. Chilling capacity will be approximately 7.5 cu ft.

According to the manufacturer, the unit is suited to all industrial low temperature applications—transformation of austenite in alloy steel, stabilization of steel, normalizing of castings, parts and material testing, and other sub-zero operations.

External dimensions of the unit are 72 by 27½ by 45 in. high, providing an unusually large chilling capacity within limited floor space. Two motors, ½ h.p. and ¾ h.p., both accessible hermetic, are provided. Temperature can be controlled from −70 to −140 F. Moisture condensation on the exterior of the cabinet is eliminated through special design.



Metal Fastening Method Eliminates Rivets, Bolts, Welds and Solder

A new, one-step method of fastening sheet metal has been announced by *Crockatt Engineering Co.,* Phelan Bldg., San Francisco. Called Williams Metalacing, the new method is said to literally button metal to metal—without any additional element such as rivets, bolts, welds or solder. It accomplishes this in one single operation with a patented punch and yieldable die, made in a range of sizes that will fasten sheet metal up to ¼ in. thick.

The process, developed by Ivan A. Williams, Portland, Ore., works with any punch press merely by inserting the Wil-

NEW SOLUTIONS FOR OLD FINISHING PROBLEMS

ENTHONE CAN SHOW YOU HOW TO DO ANY OF THE FOLLOWING:

1. Remove rust and scale from steel in an alkaline solution ***without any attack on the steel***
2. Strip nickel, lead, tin, solder, silver and copper from steel without any attack on the steel
3. Electroplate on aluminum for soldering
4. Remove excess silver solder from steel
5. Phosphate and clean steel in one operation
6. Prevent rusting of steel during drying or storage
7. Shorten alkali cleaning time to seconds.
8. Strip enamels from plastics
9. Remove heat scale from copper alloys without etching the base metal
10. Chromate zinc and cadmium for high salt spray resistance

KEEP UP TO DATE. ***Write for check list of Enthone literature on over 60 products and processes for better metal finishing.***

METAL FINISHING
PROCESSES

ENTHONE
INCORPORATED

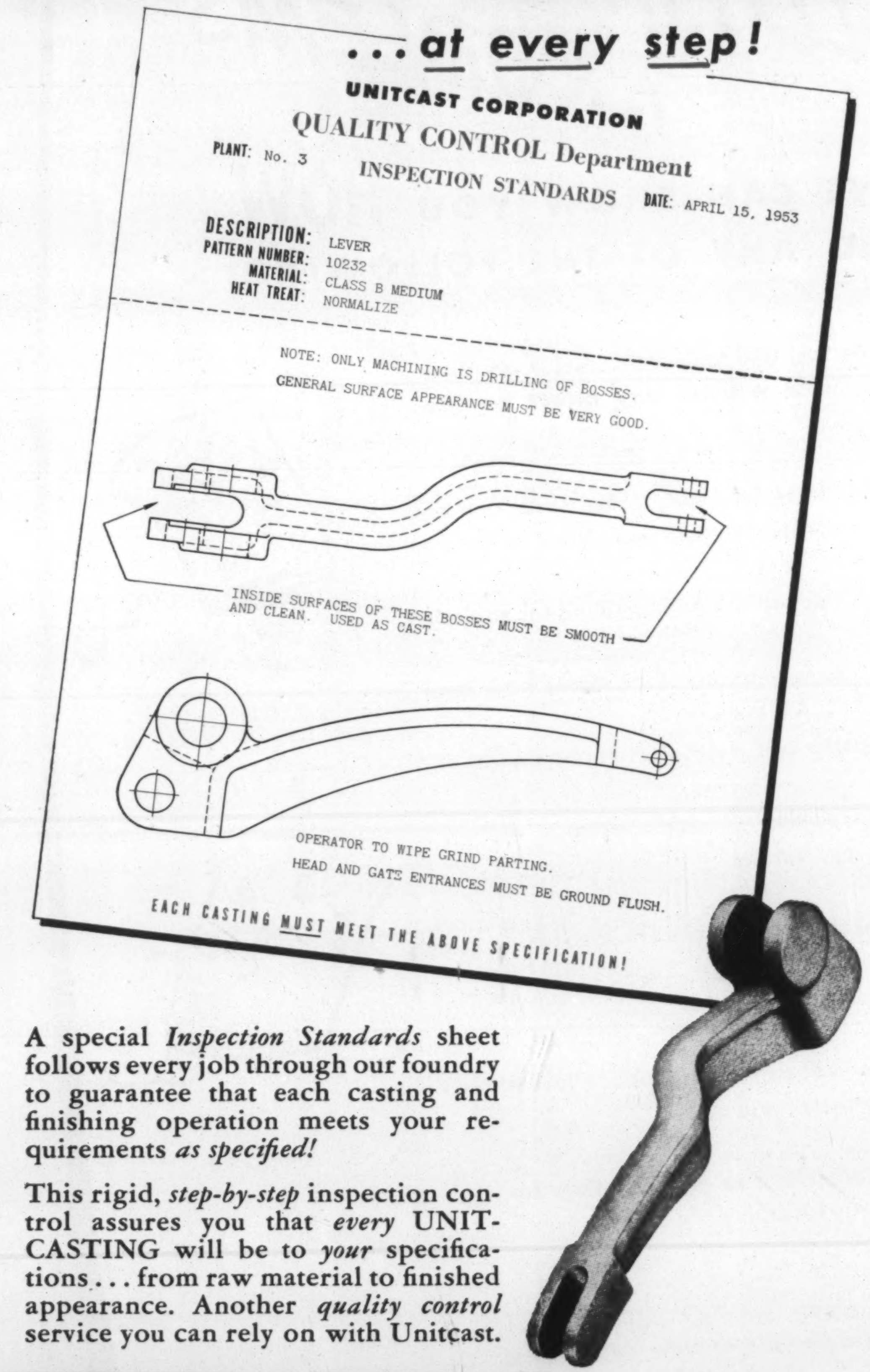
442 ELM STREET
NEW HAVEN, CONNECTICUT

ELECTROPLATING
CHEMICALS

NO. 1
IN A
SERIES

UNITCASTINGS
are consistently better!

MORE RIGID INSPECTION



... at every step!

UNITCAST CORPORATION
QUALITY CONTROL Department
PLANT: No. 3
INSPECTION STANDARDS
DATE: APRIL 15, 1953

DESCRIPTION: LEVER
PATTERN NUMBER: 10232
MATERIAL: CLASS B MEDIUM
HEAT TREAT: NORMALIZE

NOTE: ONLY MACHINING IS DRILLING OF BOSSES.
GENERAL SURFACE APPEARANCE MUST BE VERY GOOD.

INSIDE SURFACES OF THESE BOSSES MUST BE SMOOTH AND CLEAN. USED AS CAST.

OPERATOR TO WIPE GRIND PARTING.
HEAD AND GATE ENTRANCES MUST BE GROUND FLUSH.

EACH CASTING MUST MEET THE ABOVE SPECIFICATION!

A special *Inspection Standards* sheet follows every job through our foundry to guarantee that each casting and finishing operation meets your requirements *as specified!*

This rigid, *step-by-step* inspection control assures you that *every* UNITCASTING will be to *your* specifications... from raw material to finished appearance. Another *quality control* service you can rely on with Unitcast.

UNITCAST
Corporation
QUALITY STEEL CASTINGS

Our steel casting specialists welcome the opportunity of working with you on your parts problems... their suggestions at the design stage can pay you continuous dividends.

Write or call . . . Unitcast Corporation, Steel Casting Division, Toledo 9, Ohio; 701 New Center Bldg., Detroit, Michigan; In Canada: Canadian-Unitcast Steel, Ltd., Sherbrooke, Quebec.

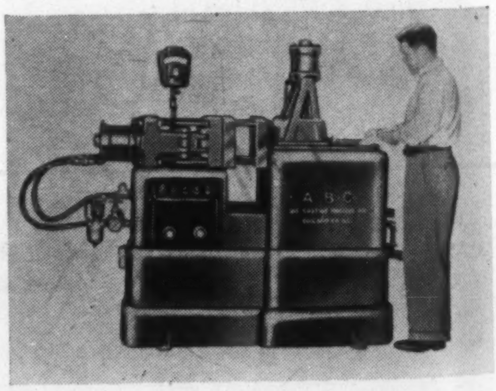
UNITCASTINGS are FOUNDRY ENGINEERED

New Materials and Equipment

liams punch and die. Cost of Metalace punches and dies, it was stated, are in line with the price of comparable tools. A set of them will permit any punch press to handle one-step fastening of a wide variety of sheet metals.

The new method is claimed to work with any material that can be sheared, drawn and upset—including all popular sheet metal types. Additionally, it readily fastens different metals together, such as steel and aluminum. Major users of the process are expected to include pipe and duct makers; sheet metal shops; truck, train and airplane body plants; stamping works; heat and ventilating factories.

Success of the new method, it was explained, stems from three separate operations that take place during the impact of the punch on the metal and the patented die. First, shearing action of the punch and die creates a parallel double incision in the two sheets of metal being fastened. Metal beneath these incisions is rammed downward, against the anvil of the die beneath the sheets and between the die's movable jaws. There the force of the impact spreads the depressed metal sideways, making it form a permanent fastening wedge or button under the surface of the bottom sheet. Thus, the parent metal itself—not any additional element such as a rivet, bolt or staple—supplies the fastening. The resulting Metalace is rectangular in outline, which means that unlike a rivet, it will not pivot.



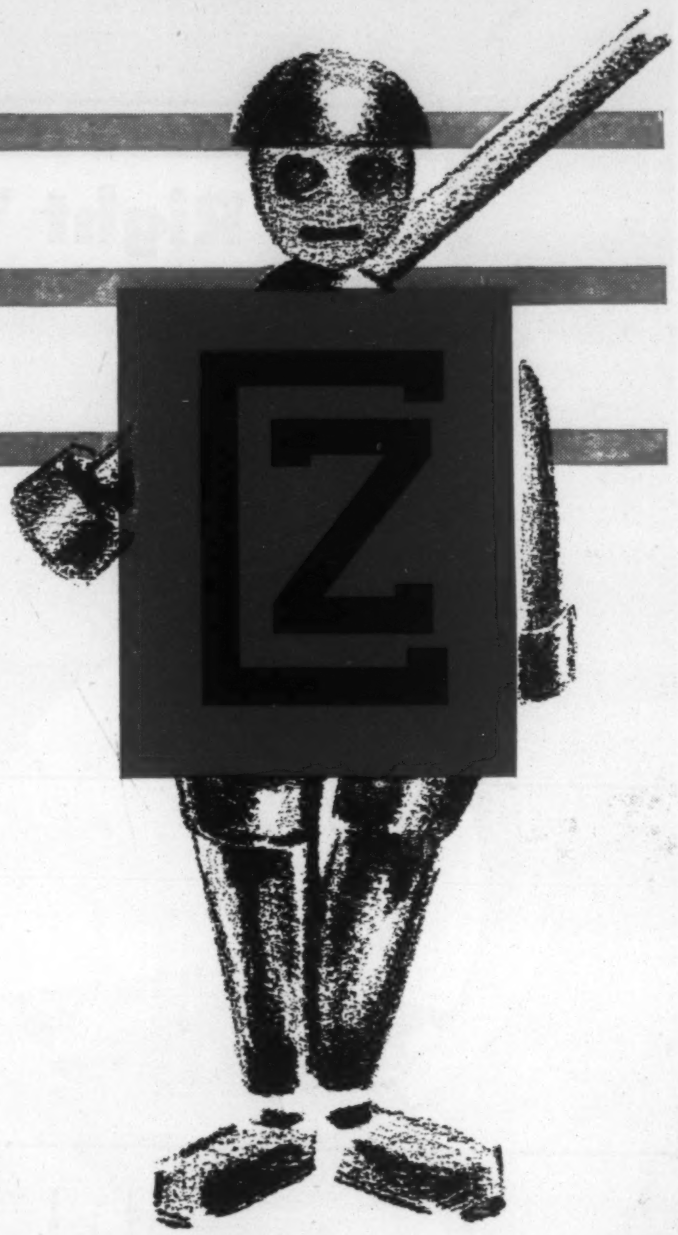
Zinc Die Casting Machine for Small Castings

A new 1½-lb zinc die casting machine, designed for smaller castings and short runs, has been introduced by the *ABC Die Casting Machine Co.*, 339 W. 112th Place, Chicago 28. According to the manufacturer, this unit was specifically designed

GUARDING THE QUALITY

OF *YOUR*

ZINC DIE CASTINGS



LICENSEES under the CZ ALLOY PLAN

A & A Die Casting Co., West Los Angeles, Calif.
The Accurate Die Casting Co., Cleveland, Ohio
Advance Pressure Castings, Inc., Brooklyn, N. Y.
Advance Tool & Die Casting Company, Milwaukee, Wis.
Badger Die Casting Corp., Milwaukee, Wis.
Central Die Casting & Mfg. Co., Inc., Chicago, Ill.
Cleveland Hardware & Forging Co., Cleveland, Ohio
Congress Drives Division, Tann Corp., Detroit, Mich.
Continental Die Casting Corp.,
  Division of F. L. Jacobs Co., Detroit, Mich.
Crown City Die Casting Co., Pasadena, Calif.
Doehler-Jarvis Corp., Pottstown, Pa.
Doehler-Jarvis Corp., Toledo, Ohio
Dollin Corporation, Irvington, N. J.
Du-Wel Metal Products, Inc., Bangor, Mich.
Federal Die Casting Company, Chicago, Ill.
Globe Imperial Corporation, Rockford, Ill.
C. M. Grey Mfg. Co., East Orange, N. J.
Heick Die Casting Corp., Chicago, Ill.
Hilfinger Corporation, Toledo, Ohio
The Hoover Company, North Canton, Ohio
Kiowa Corporation, Marshalltown, Iowa
Paul Krone Die Casting Co., Chicago, Ill.
Madison-Kipp Corporation, Madison, Wis.
Milwaukee Die Casting Company, Milwaukee, Wis.
Monarch Aluminum Mfg. Co., Cleveland, Ohio
Mt. Vernon Die Casting Corp., Mt. Vernon, N. Y.
Paragon Die Casting Company, Chicago, Ill.
Parker White Metal Co., Erie, Pa.
Precision Castings Company, Inc., Fayetteville, N. Y.
Precision Castings Company, Inc., Cleveland, Ohio
Precision Castings Corp., Chicago, Ill.
Pressure Castings, Inc., Cleveland, Ohio
Racine Die Castings Co., Racine, Wis.
St. Louis Die Casting Corporation, St. Louis, Mo.
Schultz Die Casting Company, Toledo, Ohio
Sterling Die Casting Co., Inc., Brooklyn, N. Y.
Stewart Die Casting Division
  of Stewart-Warner Corp., Bridgeport, Conn.
Stewart Die Casting Division
  of Stewart-Warner Corp., Chicago, Ill.
Stroh Die Moulded Casting Co., Milwaukee, Wis.
The Superior Die Casting Company, Cleveland, Ohio
The Tool-Die Engineering Co., Cleveland, Ohio
Twin City Die Castings Company, Minneapolis, Minn.
Union Die Casting Co., Ltd., Los Angeles, Calif.
Universal Die Casting Company, Los Angeles, Calif.
Wells Die Casting Co. of Calif., San Francisco, Calif.
Western Die Casting Co., Emeryville, Calif.

At no extra cost, you enlist the services of an extra guardian when you have your die castings made by one of the listed die casters, licensed CZ producers.

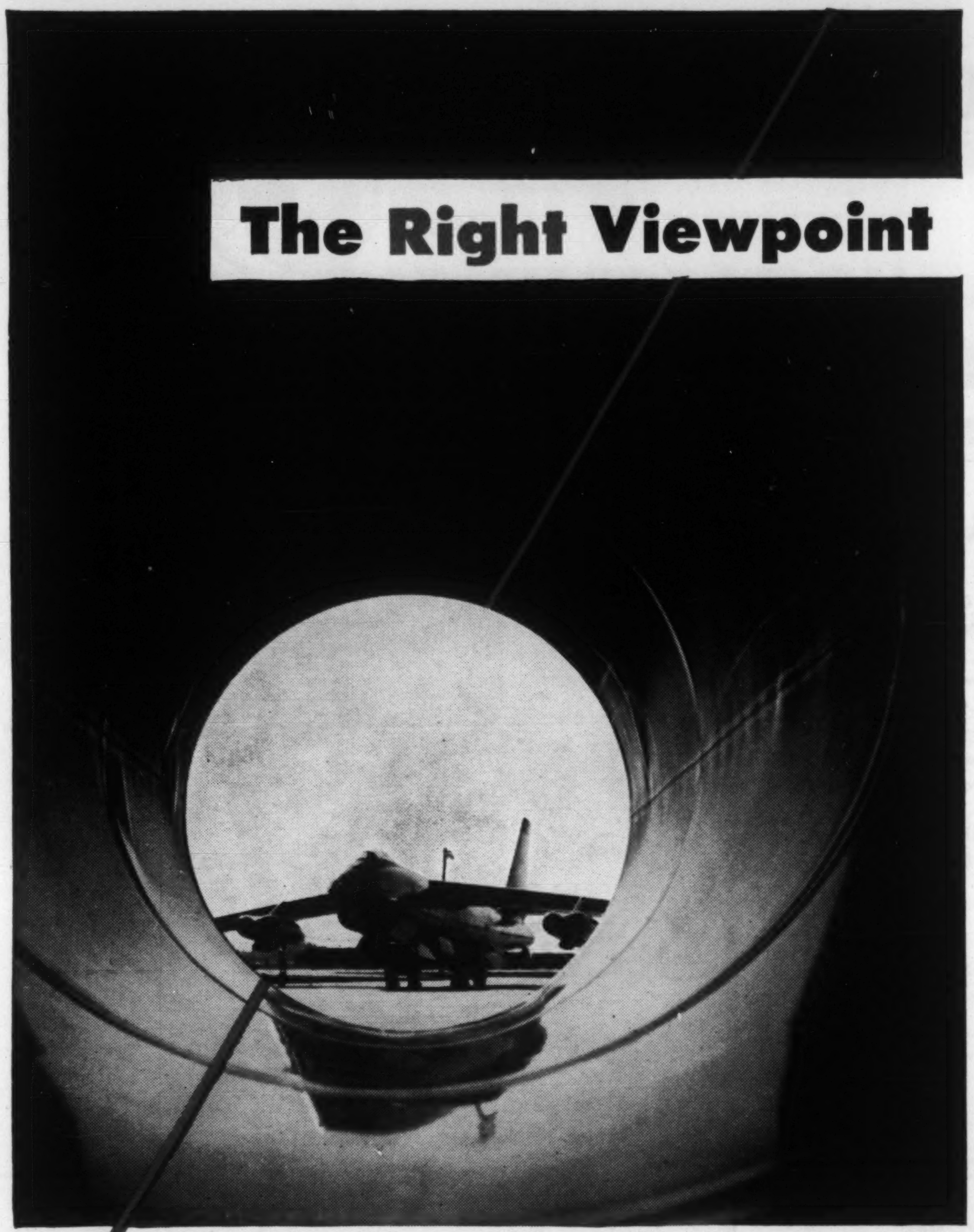
Under the **Certified Zinc Alloy Plan,** your die castings are subject to periodic, searching scientific scrutiny to make certain that they are *on grade,* that the alloy meets the specifications *you* set.

CZ stands guard on your every job to make sure that each and every one of your die castings is of a consistently superior quality.

For full details of the CZ Plan, write today without obligation.

AMERICAN DIE CASTING INSTITUTE, INC.

366 MADISON AVENUE NEW YORK 17, N. Y.



The Right Viewpoint

When you're thinking about aluminum or magnesium castings, you need the services of an organization with the right viewpoint.

We're referring, of course, to the right viewpoint toward the best possible use of these two light metals . . . ability to do the job; . . . service; . . . adequate facilities for production; . . . experience.

We here at Wellman like to think we have a combination of all these things . . . trained, interested personnel, three complete foundries and a modern pattern shop, almost a half century of experience in solving casting problems.

Why don't you try us and see how we look from your viewpoint?

- **Well-Cast Aluminum and Magnesium Castings**
- **Well-Made wood and metal patterns**

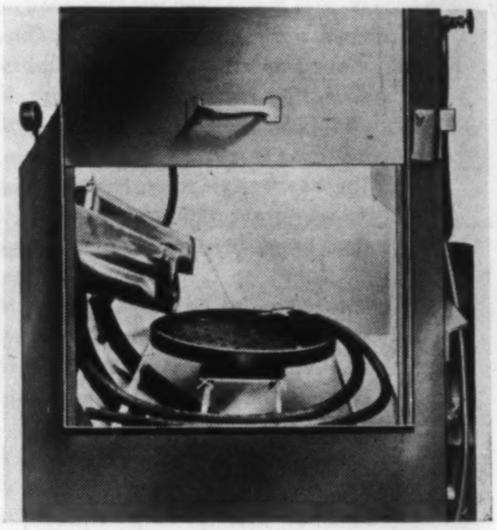
Write today for our new catalog No. 53

THE WELLMAN BRONZE & ALUMINUM CO.

DEPT. 30, 12800 SHAKER BLVD., CLEVELAND 20, OHIO

for those companies whose needs do not require a large machine, but who have need for fast cycling equipment to produce small sound castings and for economical short run production.

Air-operated, the unit is capable of a free cycling speed in excess of 1000 shots per hr. In addition to easy set-up and operation, the machine's lightening production speed makes inexpensive single cavity molds practical and profitable. Its rugged construction is designed for trouble-free, efficient operation. Additional features of the unit, Model 1500, include: an electronically controlled panel; 10- by 10- by 2½in. die blocks; four tie bars; and semi-automatic cycling with adjustable timing dwell on opening and closing of the toggle.



Wet Blaster for Small Pieces

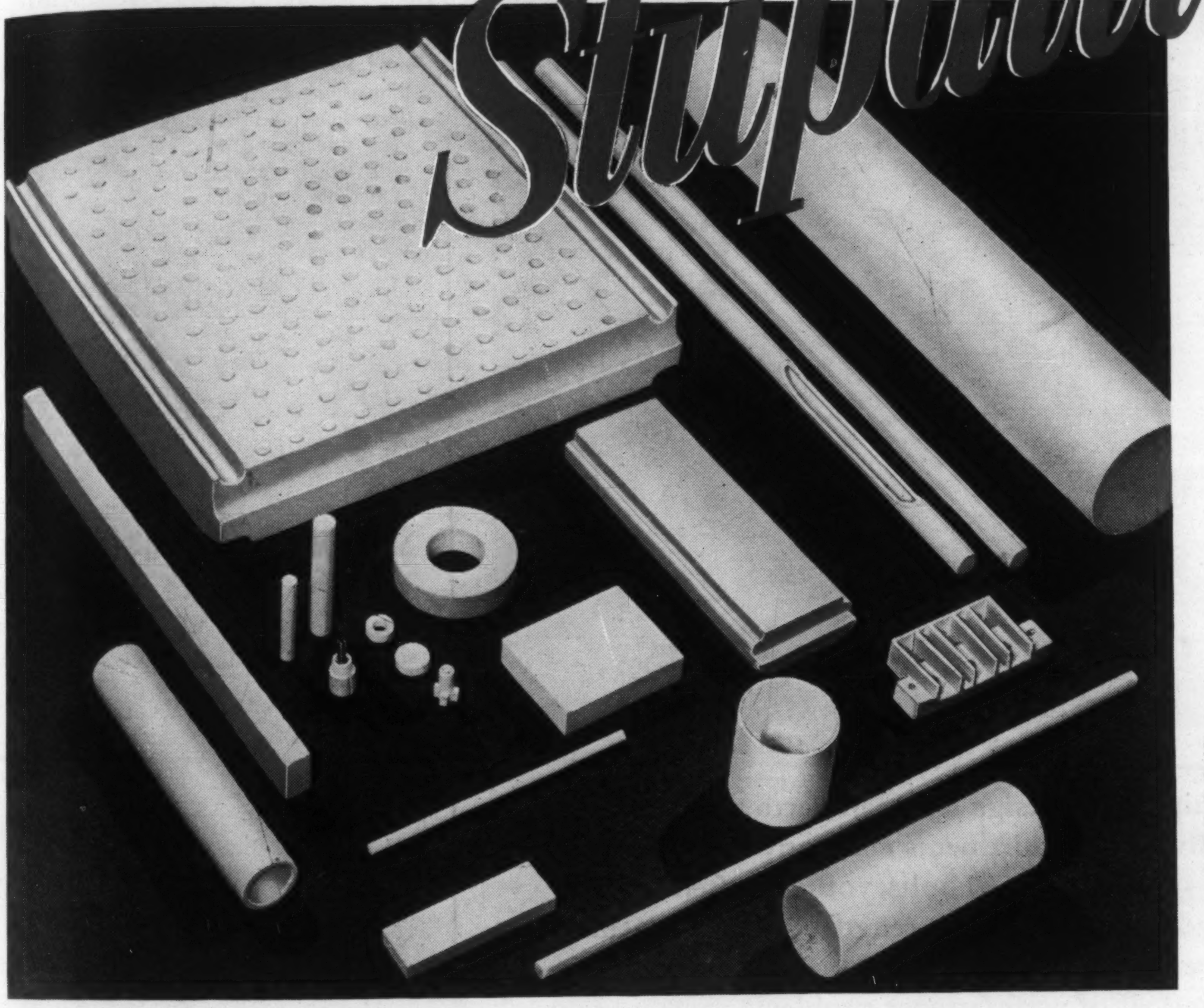
Addition of a new model to its line of wet blasting machines has been announced by *American Wheelabrator & Equipment Corp.*, 1148 S. Byrkit St., Mishawaka, Ind.

Known as the Model 30 Liquamatte, the unit is intended for precision cleaning and finishing applications involving small pieces that can be lifted and handled manually. Typical applications are in the manufacture and maintenance of small stamping dies, diecasting dies, and drawing dies; in the manufacture and maintenance of glass, plastic, and the smaller rubber molds; the reconditioning of valves, pistons, rods, etc.; reconditioning plant equipment like oil burners; surfacing tools, such as drills, reamers and taps before and after plating; cleaning oxides from tungsten carbide tips before brazing them to cutting tools; blending different types of finishes on aluminum; removing heat treat scale; deburring; cleaning out recesses in embossing punches and knurled

Thermal Shock

can't harm parts made of

Stupalith



Stupalith ceramic parts are made by pressing, extrusion, casting or ramming. A high degree of uniformity and close tolerances are readily maintained.

Low-Expansivity Ceramic Material

Where thermal shock conditions prevail, parts made of STUPALITH will withstand extremely severe service. Stupakoff makes parts ranging from a fraction of an ounce to several pounds in weight, in simple or intricate shapes.

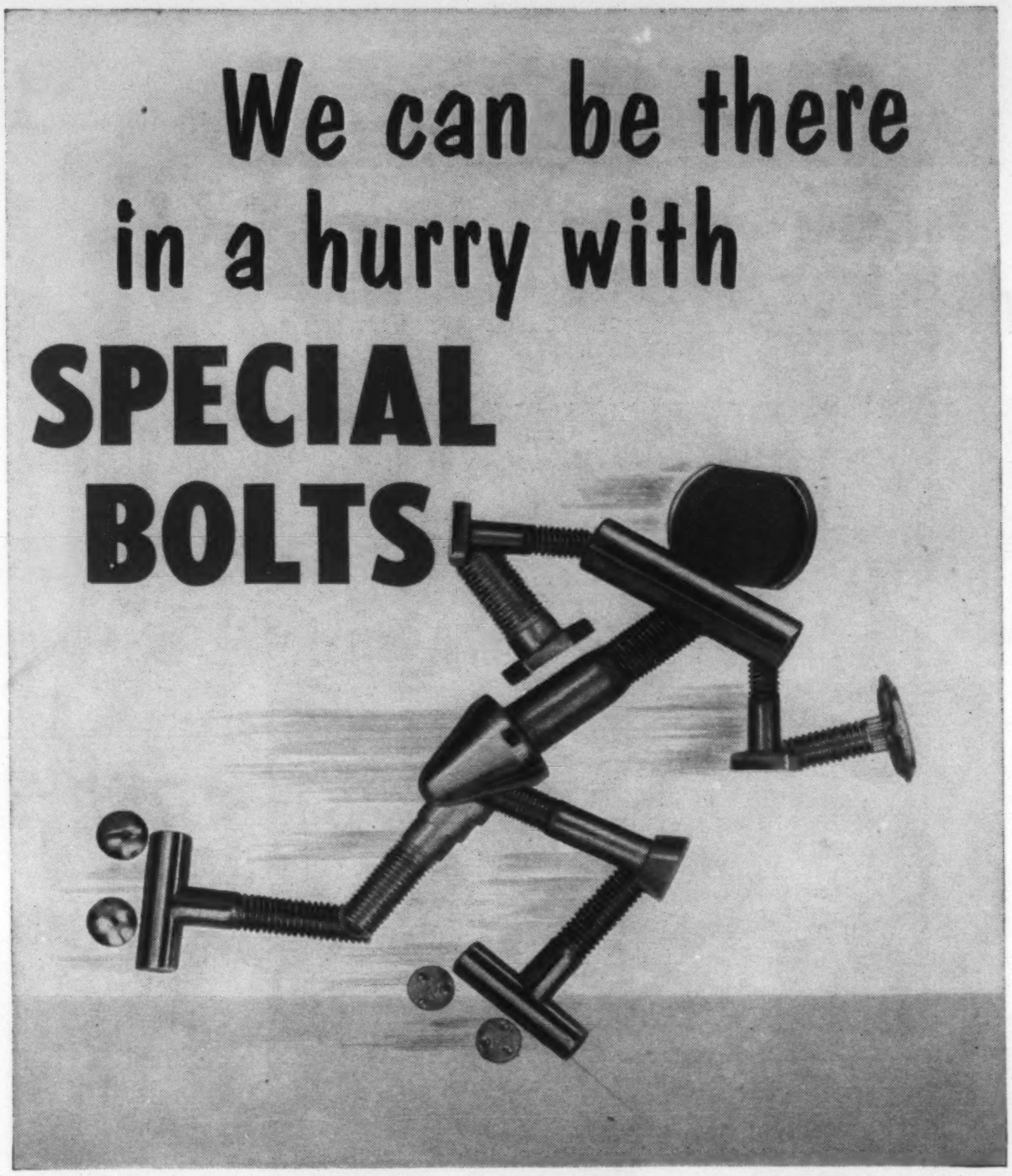
Two principal compositions are ordinarily employed: "zero" expansivity compositions, and non-porous compositions having near-zero expansivities. By varying the ingredients and processing of these compositions, parts having desired expansivity characteristics (negative or low positive) are obtained. For parts requiring a high degree of dimensional accuracy, our production process includes machining or grinding to precision tolerances. Safely used at temperatures up to 2400° F.

Stupakoff will be glad to design and produce in STUPALITH, parts having the resistance to thermal shock or the expansivity your application demands.

Stupakoff
STUPALITH

Send for descriptive Bulletin 1051

Stupakoff
CERAMIC & MANUFACTURING CO.
LATROBE, PENNSYLVANIA



We are equipped to design and manufacture special bolts to your individual requirements efficiently and quickly.

By using special Circle Ⓑ bolts, you can often simplify design . . . add extra holding strength . . . speed assembly . . . and lower unit costs.

In bringing all of your fastener problems to us . . . you receive the attention of specialists who can demonstrate the practical advantages of adopting special bolts . . . and who can *also* supply your requirements for standard fasteners.

It will cost you nothing to get the facts. Simply write us.

BUFFALO
BOLT COMPANY
Division of Buffalo-Eclipse Corporation
North Tonawanda, N. Y.
Sales Offices in Principal Cities

PRODUCERS OF CIRCLE Ⓑ PRODUCTS — BOLTS • NUTS • RIVETS AND SPECIAL FASTENERS

New Materials and Equipment

pressing rollers; and cleaning for general inspection.

Fine mesh abrasives, suspended in water, are propelled at the work by compressed air. The abrasive slurry is made up of 25 lb of abrasive and 5 gal of water. Since such fine mesh abrasives are used (80 to 2500 mesh), close tolerance dimensions are maintained, and sharp corners, lines and lettering in patterns remain undamaged. Flat surfaces, knurling, thin-walled sections, and other normally vulnerable areas remain unchanged. Tolerances of 0.0001 in. can be maintained where required.

Silver-Bearing Stainless Steel Solder

Development of a new high capillary silver-bearing stainless steel solder which is applicable with a soldering iron or torch at 430 F has been announced by *All-State Welding Alloys Co., Inc.*, White Plains, N. Y. According to the company, the new solder costs less than silver brazing alloys, is easier and less expensive to apply, and has somewhat the same affinity for all metals. Thin layers are the strongest. Also, it compares favorably with the other silver alloys in its adaptability to standard manufacturing, installation and maintenance procedures. It can be chromium plated.

The new product, All-State No. 430 Silver-Bearing Stainless Steel Solder, contains neither lead, zinc nor cadmium. Unusual physical properties in the following test data derive primarily from its silver content and the unusual interalloys formed between different metals.

Copper to Copper
Tensile: 14,300 psi
Shear: 11,200 psi
Elong. in
2 In.: 21%

Average Physicals on Interconnecting Stainless, Copper, Brass, etc.
Tensile: 10,000 to 28,000 psi
Shear: 10,000 to 15,000 psi
Elong. in
2 In.: 10-28%
(Actual physical properties vary with base metal . . . . . . depend on strength of the interalloy layer.)

Characteristics of the deposited solder include color that closely matches stainless steel and that remains stable. The deposit is nontoxic and is not brittle. Movement

tool steel is the cornerstone of our business

Just as the cornerstone is of fundamental importance to a building, tool steel is the base of our business. And ever since we were founded — now over 50 years ago — we have been proud of our reputation as the nation's leading producer of tool steels.

We have always given our customers what they needed — quality and service — regardless of their volume of business or the general supply and demand situation. During last year's steel shortage, for instance, all our customers had their share of our production.

You too, can benefit from our long experience in this field through our freely available metallurgical service . . . and from our reliable delivery service through our fully stocked warehouses, conveniently located all over the country.

SEND TODAY for the unique Crucible Tool Steel Selector — a twist of the dial gives the tool steel for your application.

Rex® High Speed Steels
Peerless Hot Work Steels
Halcomb 218
Chro-Mow®
Sanderson Carbon Tool Steels
Ketos®
AirKool Die Steel
Airdi® 150
Nu-Die V Die Casting Steel
CSM 2 Mold Steel
La Belle® Silicon #2
Atha Pneu

SPECIFY
YOUR TOOL STEELS
BY
THESE
BRAND NAMES

Crucible Steel Company of America
Dept. MM, Chrysler Building, New York 17, N. Y.

Name______________________________
Company____________________ Title_______
Address___________ City________ State_____

9" diameter, 3-colors

CRUCIBLE **first name in special purpose steels**

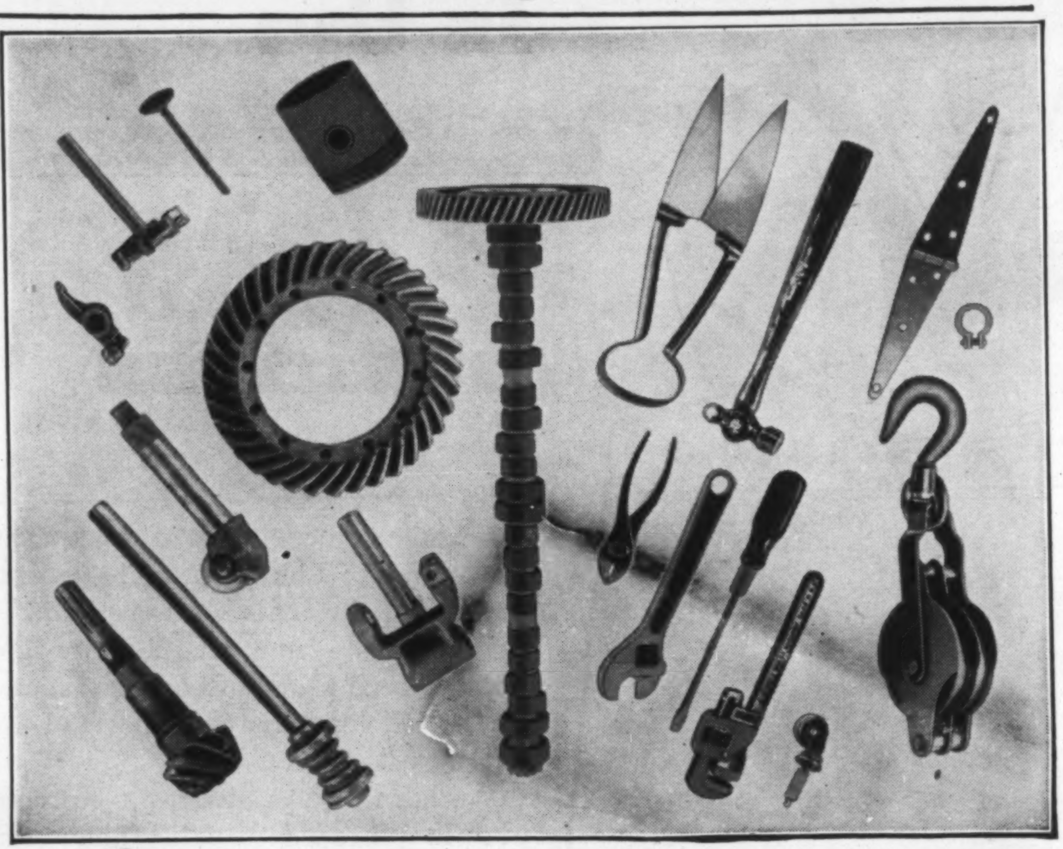
53 *years of* Fine *steelmaking*

TOOL STEELS

CRUCIBLE STEEL COMPANY OF AMERICA · TOOL STEEL SALES · SYRACUSE, N. Y.

AMERICAN CHEMICAL PAINT COMPANY
AMBLER PENNA.

Technical Service Data Sheet
Subject: RUST PROOFING WITH PERMADINE®



Steel parts that have been Permadized and then **"sealed"** with a rust-preventive oil such as "Granoleum" are effectively protected from rust. And, if the oiled "Permadine" coating should be damaged, rusting will not spread beyond the area of exposure.

Note: Automotive and other rubbing parts subject to friction are usually given "Thermoil-Granodine" manganese-iron phosphate coatings for both wear-resistance and protection from corrosion.

DATA ON THE "PERMADINE" COATING

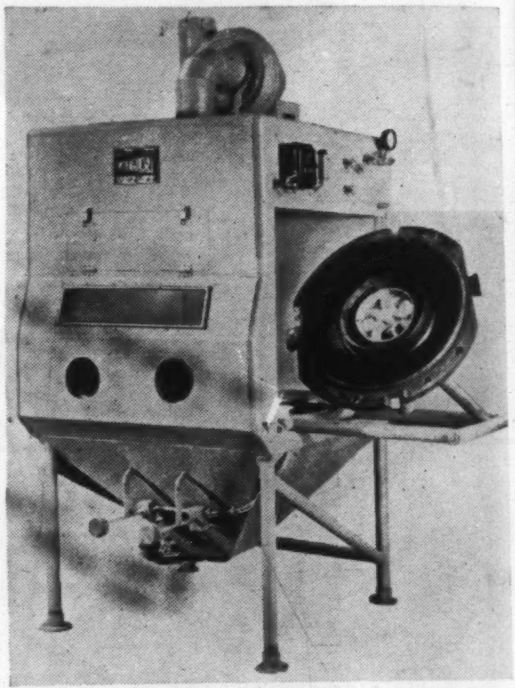
Type of coating	Zinc phosphate
Object of coating	Rust and corrosion prevention
Typical products treated	Nuts, bolts, screws, hardware items, tools, guns, cartridge clips, fire control instruments, metallic belt links, steel aircraft parts, certain steel projectiles and many other components
Government Specifications	U.S.A. 57-0-2C; Type II, Class B MIL-C-16232, Type II U.S.A. 51-70-1, Finish 22.02, Class B AN-F-20 Navy Aeronautical M-364 JAN-L-548
Scale of production	Large or small volume; large or small work
Method of application	Dip Barrel tumbling, racked or basketed work
Equipment notes	Immersion tanks of suitable capacity. Cleaning and rinsing stages can be of mild steel. Coating stage can be of heavy mild steel or stainless steel.
Chemicals required	"Permadine" No. 1
Pre-cleaning methods	Any common degreasing method can be used, Alkali cleaning ("Ridosol"), Acid cleaning ("Deoxidine"), Emulsion-alkali cleaning ("Ridosol" - "Ridoline"); vapor degreasing, solvent wiping, etc., are examples. Acid cleaning may need to follow other cleaning methods if rust or scale is present.
Bath Temperature	190° - 205°F.
Coating time	20 - 40 minutes
Coating weight range	1000 - 4000 mgs. per sq. ft.
Technical Service Data Sheets	No. 7-20-1-2 T.M. No. 5

CHEMICALS ACP PROCESSES

WRITE FOR FURTHER INFORMATION ON "PERMADINE"
AND YOUR OWN METAL PROTECTION PROBLEMS

CHEMICALS ACP PROCESSES

of the plastic joint does not affect solidus strength, as in the case of lead-tin solders. Recommended applications are broadly described as high-conductivity electrical connections, corrosion resistant assemblies, and fabrications to operate at temperatures too high for lead-tin solders. It can be used on copper tubing, refrigeration coils, etc., where contact is made with foodstuffs.



Jet Blast Liquid Abrasive Blasting Machine

Availability of a redesigned jet blast liquid abrasive blasting machine designed to clean, finish, burr, blend or etch a wide variety of dies, molds, tools and other parts, has been announced by *R. W. Renton and Co.,* 808 Addison Rd., Cleveland 3. The new machine has been engineered for around-the-clock use without costly down-time for maintenance. The liquid slurry is drawn up by siphon injection and propelled from the blasting nozzle by means of a high velocity air stream. The only moving part within the cabinet is the blower, which is used to ventilate the cabinet. Consequently, there are no critical wear points which might necessitate frequent servicing.

The new machine is said to feature maximum versatility. It is designed to handle abrasives ranging from 60 to 5000 standard screen size, and new design permits fast change-over of abrasive slurry. Reversible pump located beneath the cabi-

13/16 R
3/16 R
11/32
1/2
OLD DESIGN
13/16 R
3/16 R
11/32
43/64
15/32
10
20
30
40
50
D C AMPERES

Crucible Alnico Magnets help ruggedize

Roller-Smith Instruments

13% smaller—same magnetic strength

When the Roller-Smith Corporation decided to ruggedize their electrical instruments to meet Military Specifications, they discovered that they needed a smaller permanent magnet — one that would do the same job as the old one they were using.

They called on Crucible's technical service for assistance. In short order, Roller-Smith's objective was attained. For through improved design, and better quality control in production, Crucible developed an alnico magnet that was 13.5% smaller and lighter than the previous one . . . but with the same magnetic strength.

The Roller-Smith story is typical of the many cases solved with Crucible Alnico Magnets, because Crucible magnets have the highest gap flux per unit of weight of any on the market. Crucible has been the leading producer of Alnico Permanent Magnets since the industry started. When you have a magnet problem, call on Crucible.

CRUCIBLE first name in special purpose steels

53 *years of* *Fine* *steelmaking*

PERMANENT ALNICO MAGNETS

CRUCIBLE STEEL COMPANY OF AMERICA, GENERAL SALES OFFICES, OLIVER BUILDING, PITTSBURGH, PA.

STAINLESS • REX HIGH SPEED • TOOL • ALLOY • MACHINERY • SPECIAL PURPOSE STEELS

DURASPUN
Nice Grain Structure!

You're looking at a polished section cut from a Duraspun Centrifugal Casting...a casting with 12-14% chromium. It tells better than words of the high quality of Duraspun Centrifugal Castings.

You get a fine, dense, uniform grain structure. Possible air pockets and blow holes are eliminated. Tensile strength is higher than with static castings.

Order Duraspun if you need pipe or tubing. Sizes run up to 15 feet in length; up to 32 inches OD; and down to ¼ inch wall thickness. Odd shaped pieces can be produced providing a circular hole passes uniformly down the center. These, of course, require specially designed casting forms.

If, before ordering or asking us to quote, you would like to know more about our work and facilities, send for our Catalog 3150.

THE DURALOY COMPANY
Office and Plant: Scottdale, Pa. • *Eastern Office:* 12 East 41st Street, New York 17, N.Y.
Detroit Office: 23906 Woodward Avenue • Pleasant Ridge, Mich.
Atlanta: J. M. TULL Metal & Supply Co. Chicago: F. O. NELSON 332 S. Michigan Avenue San Francisco: JOHN D. FENSTERMACHER 1241 Taylor Street
METAL GOODS CORP. Dallas • Denver • Houston • Kansas City • New Orleans • St. Louis • Tulsa

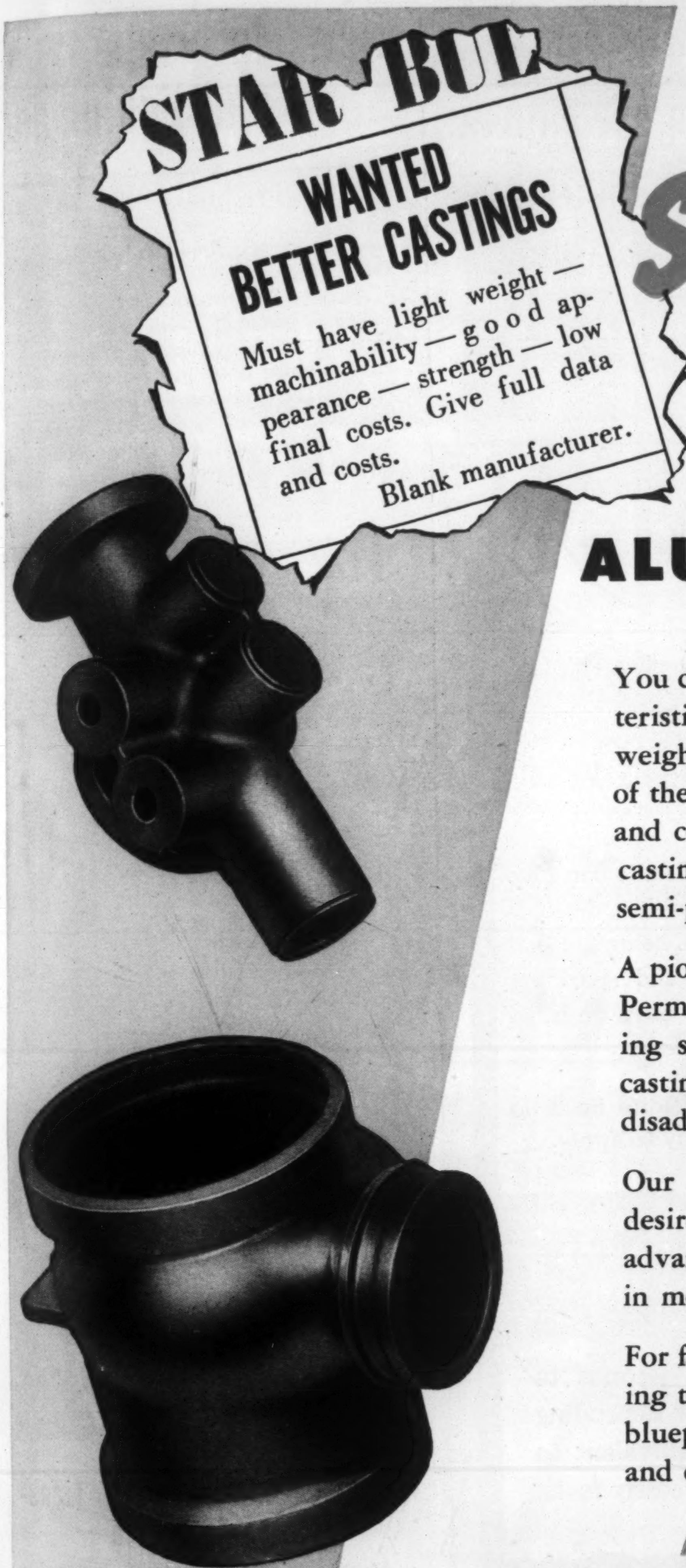
New Materials and Equipment

net effects complete change in less than 5 min. A special method of maintaining the slurry in suspension permits higher concentration of abrasive at the point of work and thereby increases speed of operation.

Size of abrasive particles, concentration of abrasives in solution, the distance between nozzle and work, and the supply air pressure can be varied to produce the results desired. The unit is said to be able to handle the most delicate cleaning problems without surface damage or dimensional alterations. It is particularly effective in removing rust, scale and other deposits, and the clean matte surface which it produces increases adherence of paint, porcelain, rubber or electroplated metals. It can effect any desired finish on any flat or irregular surface. Sharp edges are retained, and metal removal can be held to 0.0001 in. This machine can be used for light burring, honing cutting faces, and for blending or removing directional grinding lines or tool marks on machined surfaces in order to reduce possible fatigue failure. In the ceramics industry, the Jet Blast is particularly useful for frosting, etching or engraving glass or pottery.

All-Purpose Industrial Cleaner Offered

Applied by a hand-sized pressure spray gun, patented Kelite Spray White (*Kelite Products, Inc.,* 1250 N. Main St., Los Angeles 12) is a new industrial cleaner which is said to effectively remove grease, oil, wax, gums, dirt, dye, ink, cutting soap, light carbon, etc., with complete safety. It can be used on metals, plastics, rubber, porcelain, composition, concrete or wood. The new product is said to accomplish rapid cleaning without heat, odor,



STAR BUL

WANTED
BETTER CASTINGS

Must have light weight — machinability — good appearance — strength — low final costs. Give full data and costs.

Blank manufacturer.

SAVE FURTHER SEARCH!

by using

PERMITE

ALUMINUM CASTINGS

You can count on each of the above desirable characteristics for your component parts when you use light-weight aluminum castings by Permite. The facilities of the Permite aluminum foundries are ultra-modern and complete for the production of aluminum alloy castings of the highest quality by the permanent mold, semi-permanent mold, or sand mold process.

A pioneer in working with aluminum and its alloys, Permite has the experience and facilities for producing strong, accurate, structurally correct aluminum castings of uniform quality, that eliminate the weight disadvantages of heavy metal parts.

Our engineers work closely with manufacturers as desired on design and alloy problems, so that full advantage of light-weight aluminum may be gained in meeting their specific parts requirements.

For facts on which to judge the advisability of changing to light-weight Permite aluminum castings, send blueprints and specifications for recommendations and cost estimates.

ALUMINUM INDUSTRIES, INC.
Cincinnati 25, Ohio
Detroit: 809 New Center Building **New York: 9 Rockefeller Plaza**
Chicago: 64 E. Jackson Boulevard

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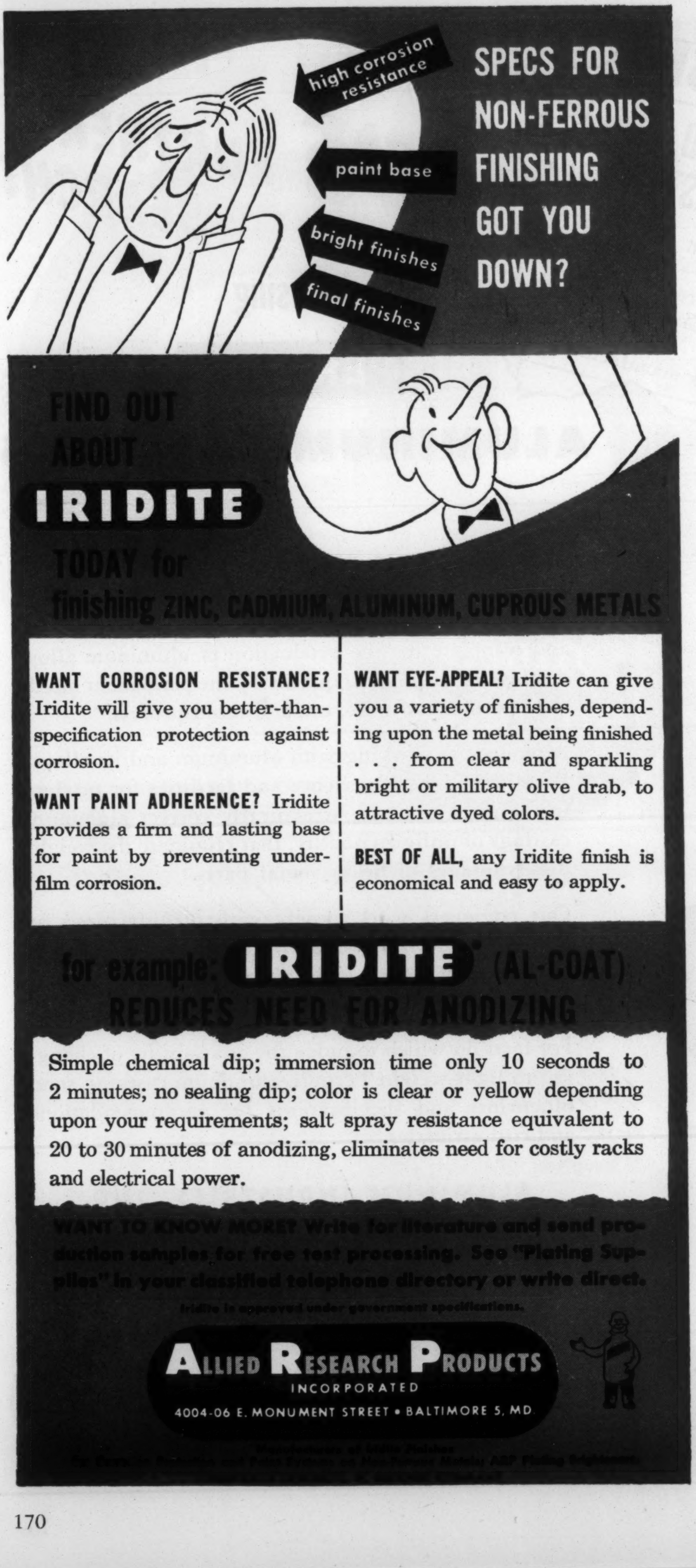

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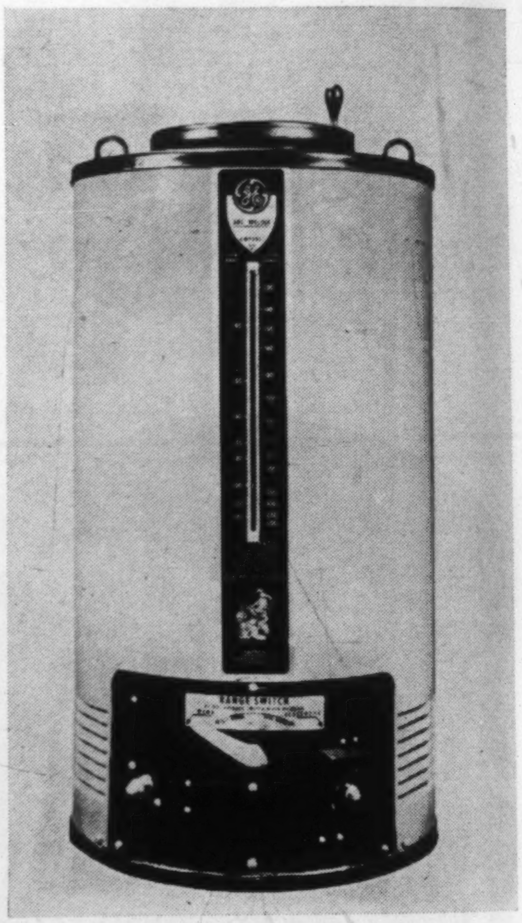

400-Amp A.C. Welding Transformer Announced

A new 400-amp single-phase a.c. welding transformer with a 60% duty cycle has been announced by the Welding Dept., *General Electric Co.*, Schenectady 5. Designated as G-E Type WK40K, the new welder provides a current range of 40 to 500 amp, and can be used with a variety of electrode sizes for repair, maintenance and construction work.

According to company engineers, the new transformer not only assures quick starting, but also incorporates arc-stabilizing capacitors, which make it easier for operators to strike and maintain an arc without popouts. This results in faster

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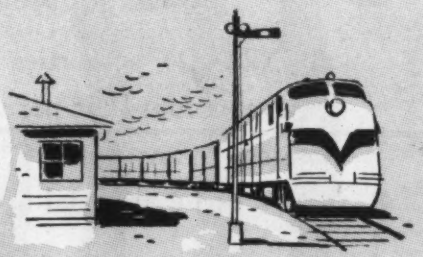

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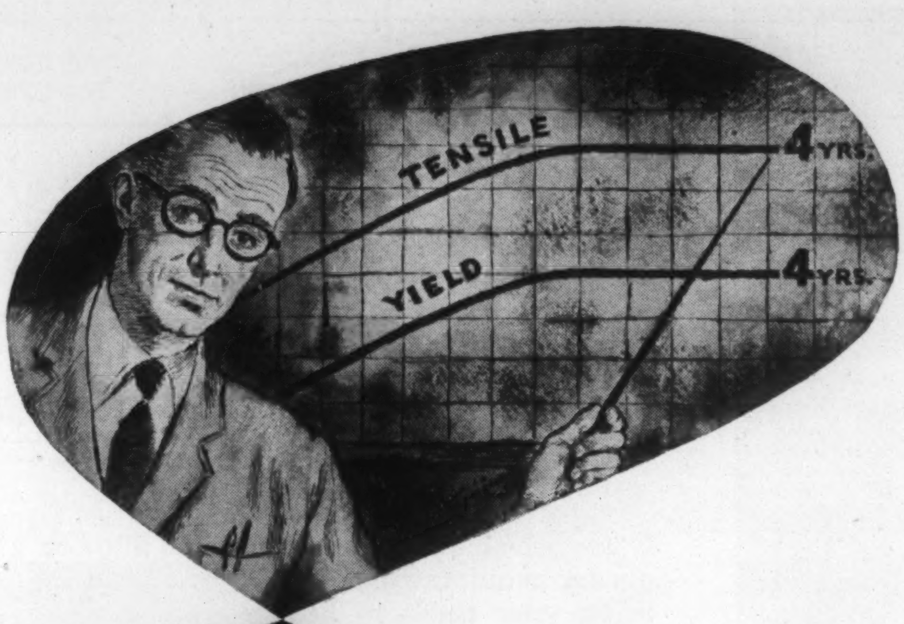
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The extra wide current range allows the use of this one machine for a wide variety of applications, from light-duty, low-current sheet metal jobs to heavier-duty, high-current industrial work. A range switch enables the operator to change quickly from high to low currents, or the reverse.

Other advantages of the new welder are longer coil life, because of silicone insulation; stepless current control permitting accurate adjustment; and built-in idlematic control for protection against electric shock.

General Purpose Welding Electrode

A new general purpose mild steel welding electrode, designed for optimum flexibility of applications with reduced operator effort, has been announced by the Welding Dept., *General Electric Co.*, Schenectady 5. Designated as G-E Type W-610-A, the new electrode is a d.c. reverse-polarity rod meeting AWS Class E-6010 specifications.

The electrode is said to facilitate butt, fillet, lap joint and edge welding in all positions. Its ability to take high currents, together with freedom from reaction pitting, fingernailing, spatter and blistering of the coating, assures a high ratio of inches-of-welding to inches-of-electrode use.

Typical applications include the welding of pipelines, steamlines, ship structural frames, bridges and all types of unclad pressure vessels and storage tanks.

As a flexible seal for limit switches exposed to weathering and temperatures below —100°F, Silastic* works where other materials fail.

Reliability is imperative in hermetically sealed limit switches used to control such aircraft parts as landing gear, bomb bay doors, turrets and flaps. Evaluation tests conducted by Electro-Snap engineers showed that Silastic was the only material flexible enough at extremely low temperatures to serve as a diaphragm-type wobbling seal. Faultless performance for over a million test cycles plus qualification under government specifications prove the excellence of the design and the superiority of Silastic.

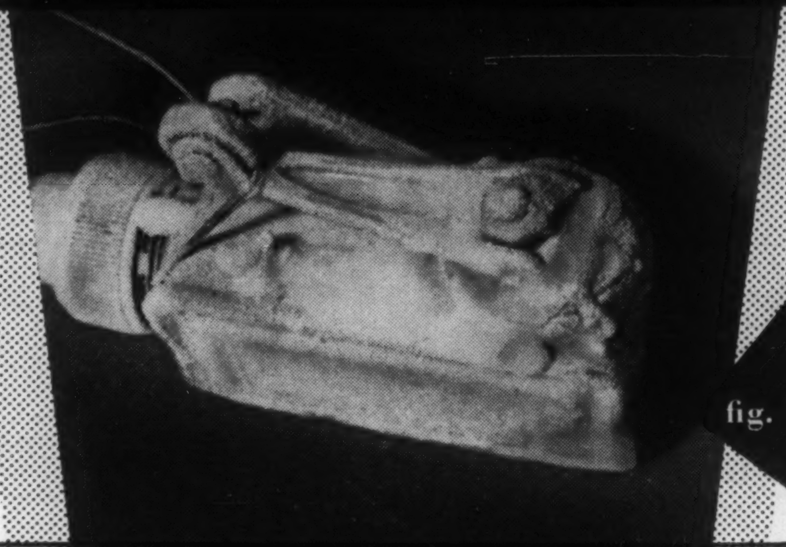

fig. 1

Actuating arm of switch held in depressed position and exposed to —100°F for several hours.

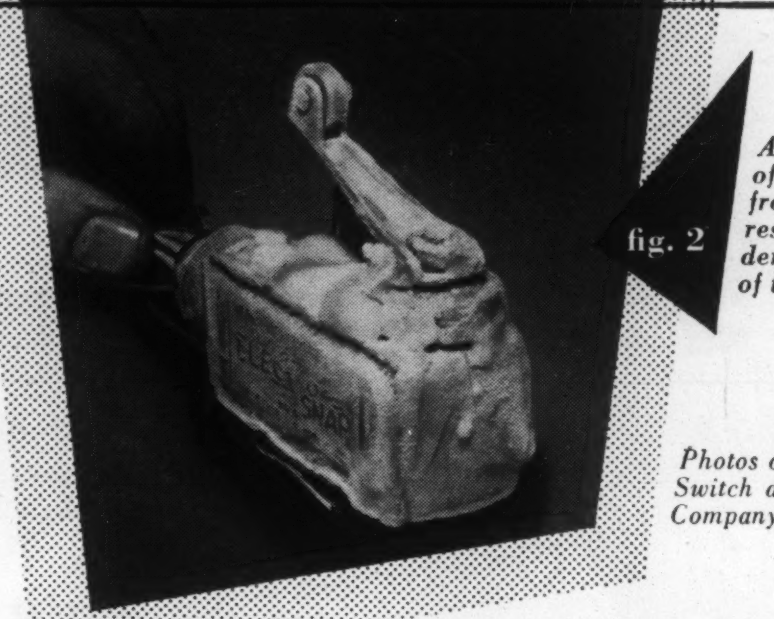

fig. 2

Actuating arm of switch released from depressed position responds instantly, demonstrating the flexibility of the Silastic seal.

Photos courtesy Electro-Snap Switch and Manufacturing Company, Chicago, Illinois.

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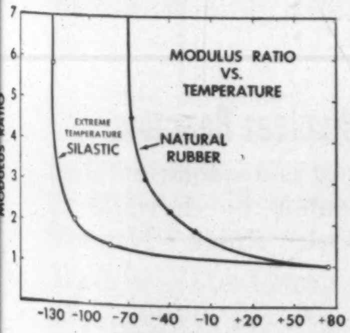
the Dow Corning silicone rubber

Silastic stocks designed for extreme temperature applications are the only materials that will retain rubbery properties after continuous long term exposure to temperatures from —80 to 300-350°F or after repeated short term exposure to temperatures from —130° to 500°F.



As a standard for low temperature performance, we call your attention to our data[1] on modulus ratios, or relative stiffening, as measured by the Gehman test method. According to these data (see Figure) the modulus for Extreme Temperature Silastic shows no appreciable change above temperatures in the range of —112 to —130°F. Rapid change in the modulus for natural rubber and for most silicone rubber stocks takes place between —40 and —70°F.

All types of Silastic show excellent resistance to oxidation, weathering and to a variety of hot oils and chemicals. Silastic stocks for electrical applications are unique even among silicone rubbers for low water absorption and excellent dielectric properties combined with good physical strength.

Data and actual performance prove that you can count on Silastic to retain both its physical and dielectric properties after long exposure to outdoor weathering or to temperatures far above and below the limits of natural or synthetic organic rubbers.

---

[1] *Polmanteer et al, Ind. and Eng. Chem. Vol. 44, Page 1576, July 1952.*

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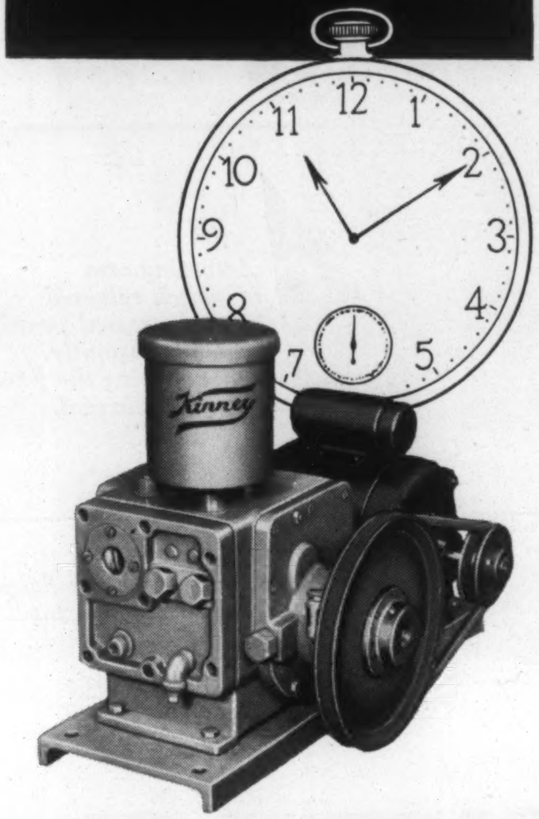

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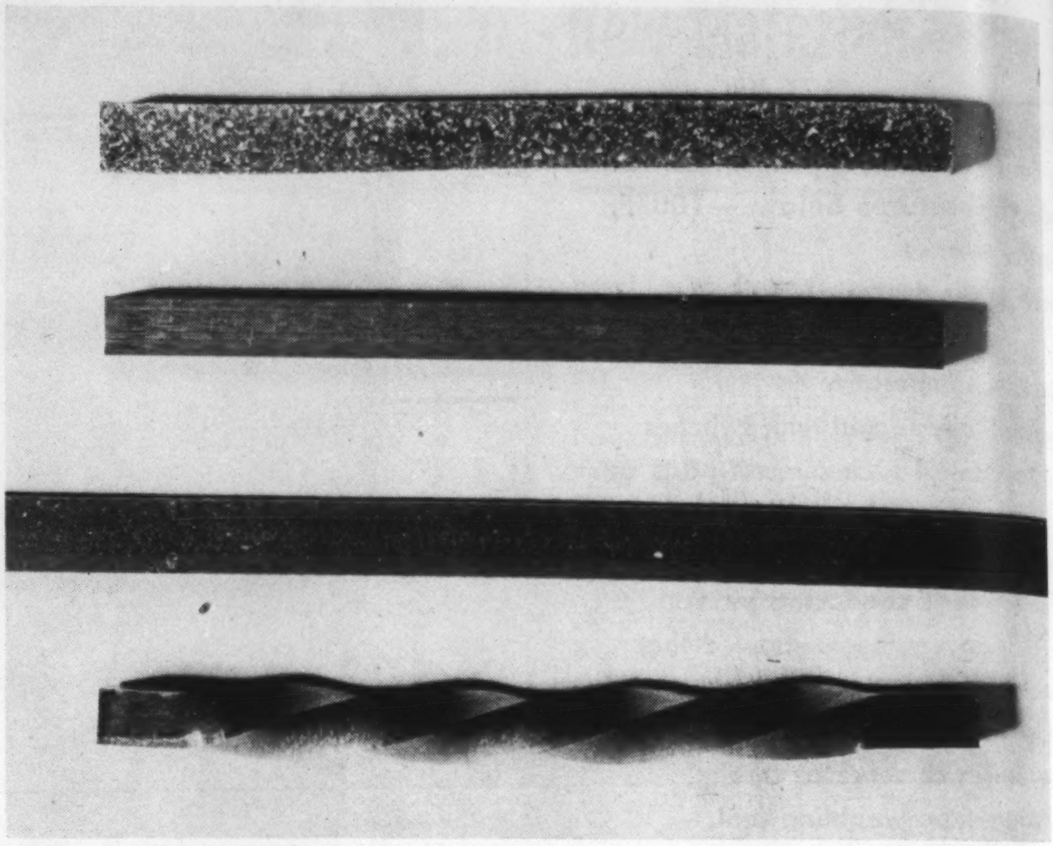

Ductile zirconium made by powder metallurgy methods. Top to bottom: as sintered, surface ground, cold reduced 50% in thickness, twisted through 360 F.

Latest Developments in Zirconium

—A Report on the Symposium at the Western Metal Congress

Reported by **HERBERT S. KALISH**
Section Head, Atomic Energy Div., Sylvania Electric Products Inc.

● THE USE OF zirconium up to a few years ago has been largely limited to its incendiary nature when finely divided, *e.g.* in photoflash lamps and flares, or for its lettering qualities, but the great future use is based on its corrosion resistance and other properties, making it a most favorable material for the chemical industry and in the construction of nuclear reactors.

The role zirconium is expected to play in the family of metals was discussed at the Western Metal Congress in Los Angeles, Mar. 23-27, 1953.

Zirconium in Nuclear Reactors

The following is a quotation from a paper presented by Edward C. Miller, of Oak Ridge National Laboratory.

"If we assume a continuing increase in the world's energy demands, new energy sources will be required eventually to augment conventional fuel sources. If a substantial part of the recoverable U^{238} and Th^{232} can be converted to fuel and utilized economically, nuclear fission may well supply a significant

(Continued on page 176)

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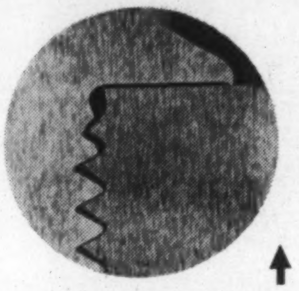
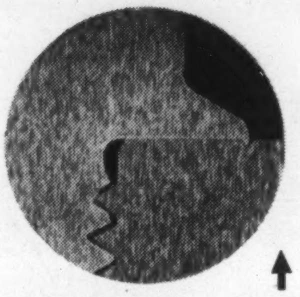
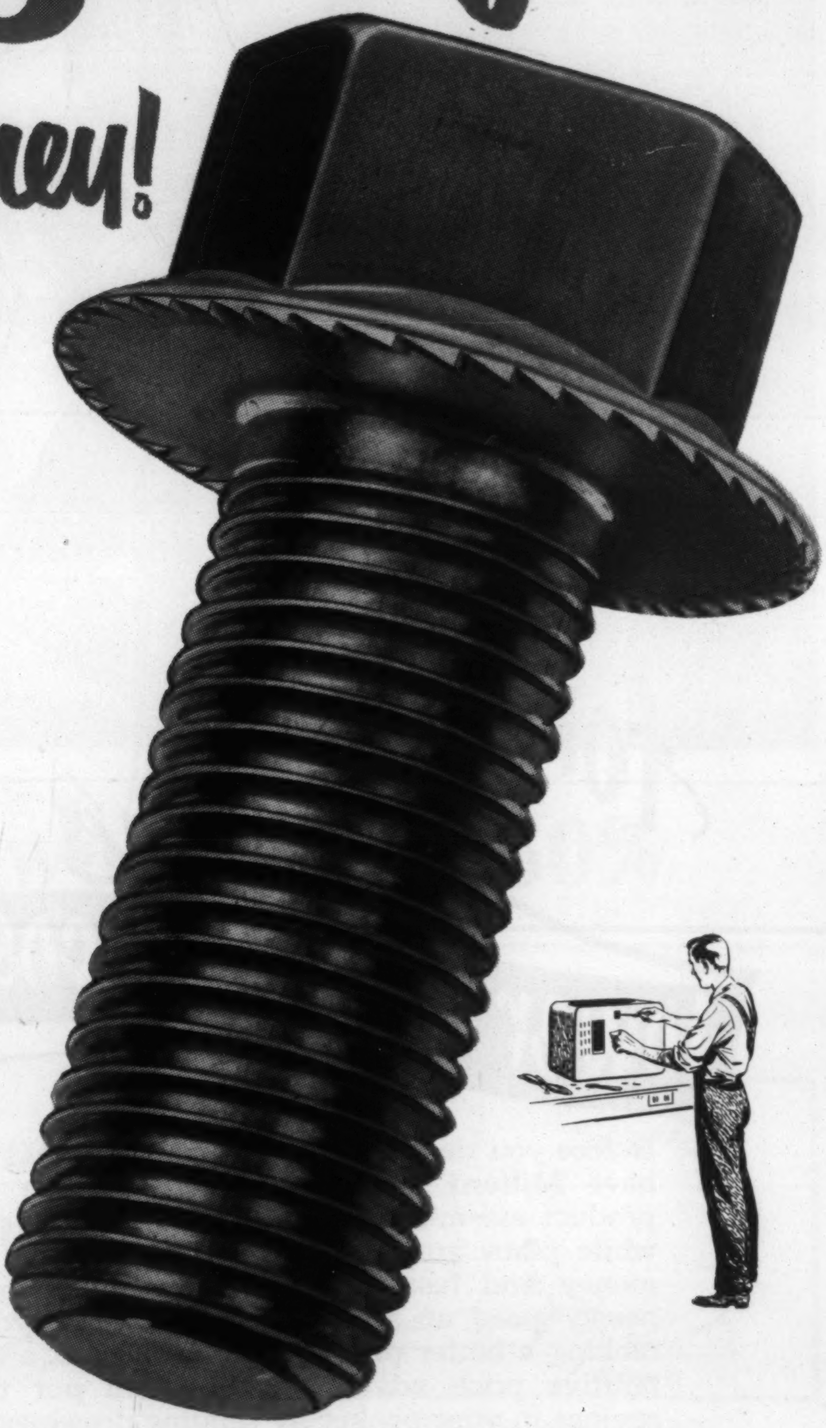

Teeth of SPIN-LOCK Screw touch bearing surface before final tightening.


Final tightening embeds teeth in surface, assuring positive locking.



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continued from page 174

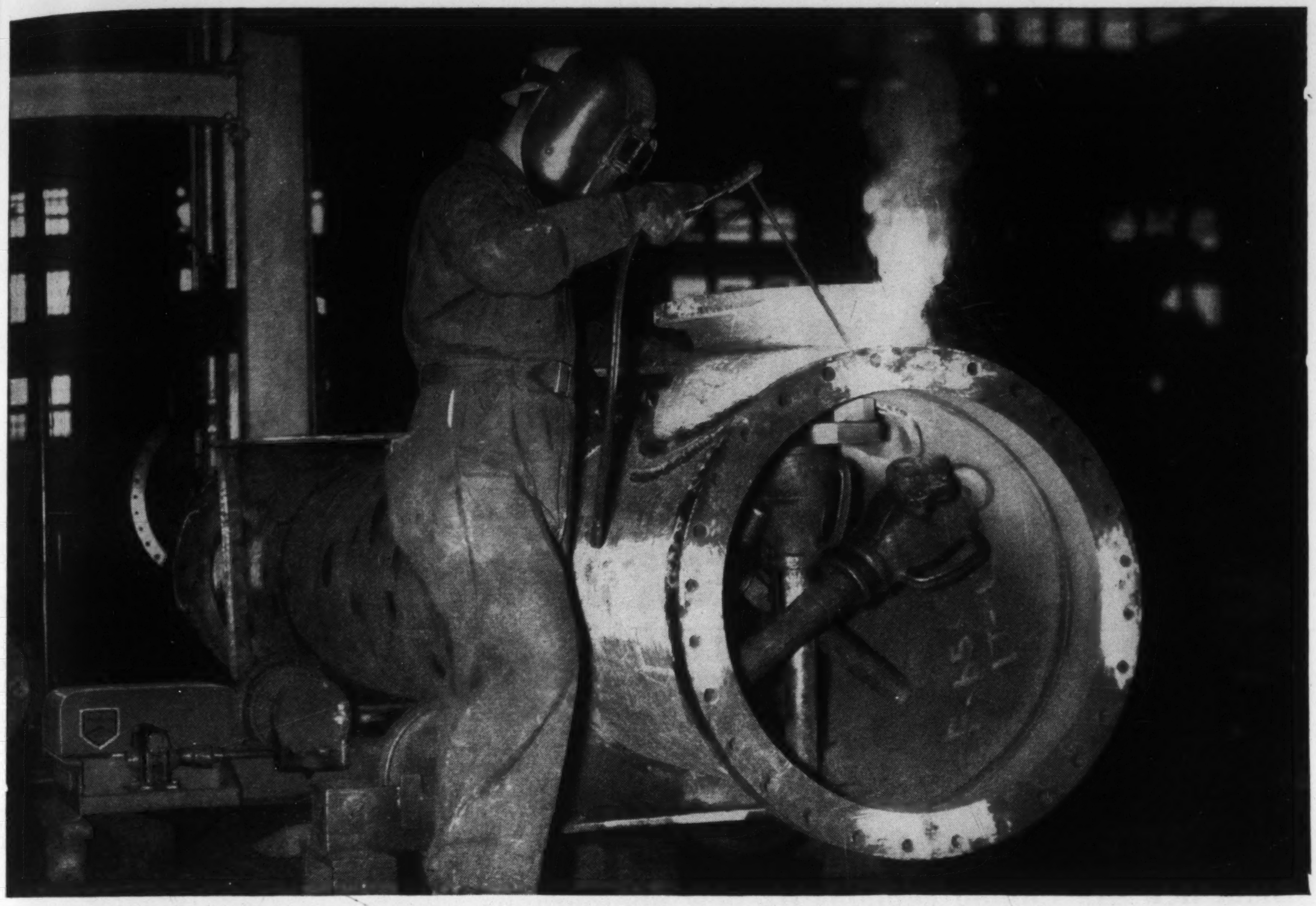
part of this demand. But, if U^{235} should be the only economically available nuclear fuel, nuclear power utilization is likely to be confined to only a small part of the specialized applications, such as mobile military power units and stationary power generation in geographically inaccessible regions, for which it is so well suited."

Nuclear cross section is the relative efficiency or probability of a nuclear reaction. Thus, absorption cross section refers to the ability of a material to absorb a neutron. The absorption of neutrons is wasteful of the available energy in uranium, thorium, or other fissionable material. As an estimate of relative efficiences, several assumptions were made for a hypothetical thermal reactor. From this calculation it was found that for one particular reactor type if zirconium was used, fuel utilization could be 12% compared to only 3.5% for stainless steel or similar structural materials. Zirconium, it is seen, is the only metal known having a high melting point and a low cross section, and thus, potential use for certain high temperature operations. It is further significant that zirconium is corrosion resistant to most media, its only shortcoming being the readiness with which it can absorb oxygen, nitrogen and hydrogen at elevated temperatures. According to Mr. Miller:

> "The successful development of a substantial nuclear power industry does not depend on any one factor, but rather on the successful solution of several problems; and among the most important of these problems is the development of low cross-section, high temperature metals and alloys for structural use. The extent to which zirconium may contribute to this solution will depend in large measure upon research of the type being presented in this symposium."

An important problem in the utilization of zirconium for nuclear purposes is the removal of the high cross section hafnium generally found in about 2 to 3% in the ore. "Practical utilization of the low neutron cross section of zirconium requires removal of substantially all the hafnium. The Oak Ridge National Laboratory's Materials Chemistry Div., was successful in devel-

(Continued on page 178)



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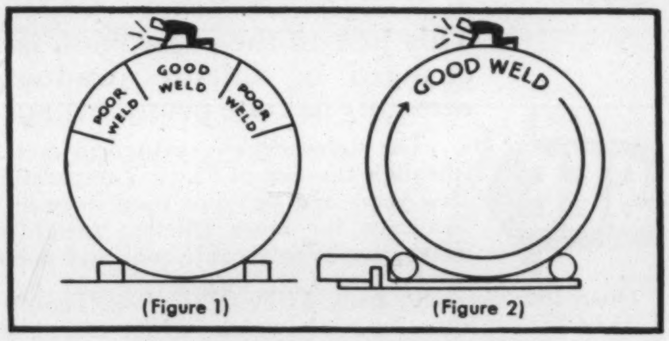
With Worthington turning rolls any welder can get better welds and turn out real footage



(Figure 1) (Figure 2)

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continued from page 176

oping a suitable chemical method, and had a pilot plant in operation in September 1949 that produced several pounds of low-hafnium zirconium per day. Further research and modification of the pilot plant operation improved the yield and the product purity and lowered the cost. At the beginning of this work, hafnium-free, crystal bar zirconium was available only in special production lots at a cost of about $1000 per lb, whereas hafnium-containing zirconium cost something less than $300 per lb. At present, the separated, hafnium-free zirconium oxide can be produced for well under $5 per lb, to which should be added the cost of converting to zirconium metal."

Manufacture of Zirconium

Mr. Stephen M. Shelton, Regional Director of the Experiment Station at Albany, Ore., described the manufacture of hafnium-free zirconium sponge. Starting with very small quantities in 1947, the experiment station at Albany has already produced ½ million lb of zirconium sponge. The present going rate is about 25,000 lb of hafnium free zirconium per month. In addition, several tons of hafnium containing less than 2% zirconium have been produced.

Zirconium produced by the Bureau of Mines had only one disadvantage over the extremely high purity iodide process crystal bar and that is in regard to oxygen content. In the considerable discussion which followed the presentation, most attention was focused on the oxygen problem. It would seem that the oxygen is now at quite low levels (on the order of 0.1 to 0.2 weight percent), that it will in no way hinder the use of this zirconium, and that there is good reason to expect even lower oxygen levels in the near future.

In the processing of zirconium, commercial zirconium tetrachloride ($ZrCl_4$) is processed to affect the hafnium separation. This process is still classified. The resultant hafnium-free zirconium oxide is mixed with carbon and a dextrin binder and briquetted. The briquettes are directly chlorinated to form a raw zirconium tetrachloride. This material, unlike the liquid titanium tetrachloride ($TiCl_4$), is a hygro-

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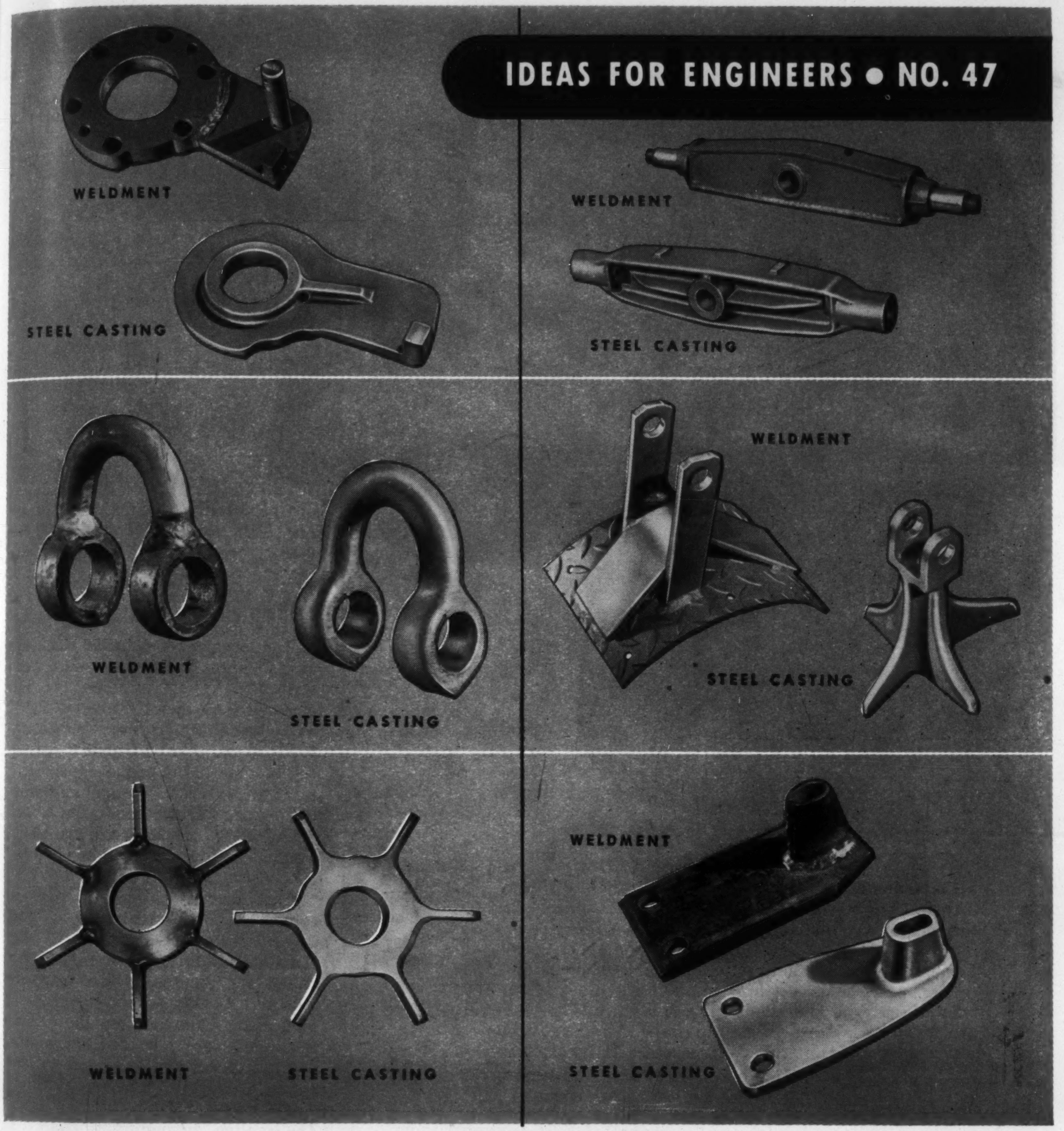
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These are a few of many smaller parts which have been *redesigned to steel castings.* They will suggest ways you can improve some of your products . . . probably with a reduction in costs. The results shown here were obtained through cooperation of the steel foundry with the manufacturer's engineering department. Perhaps your steel foundry can be equally helpful to you.

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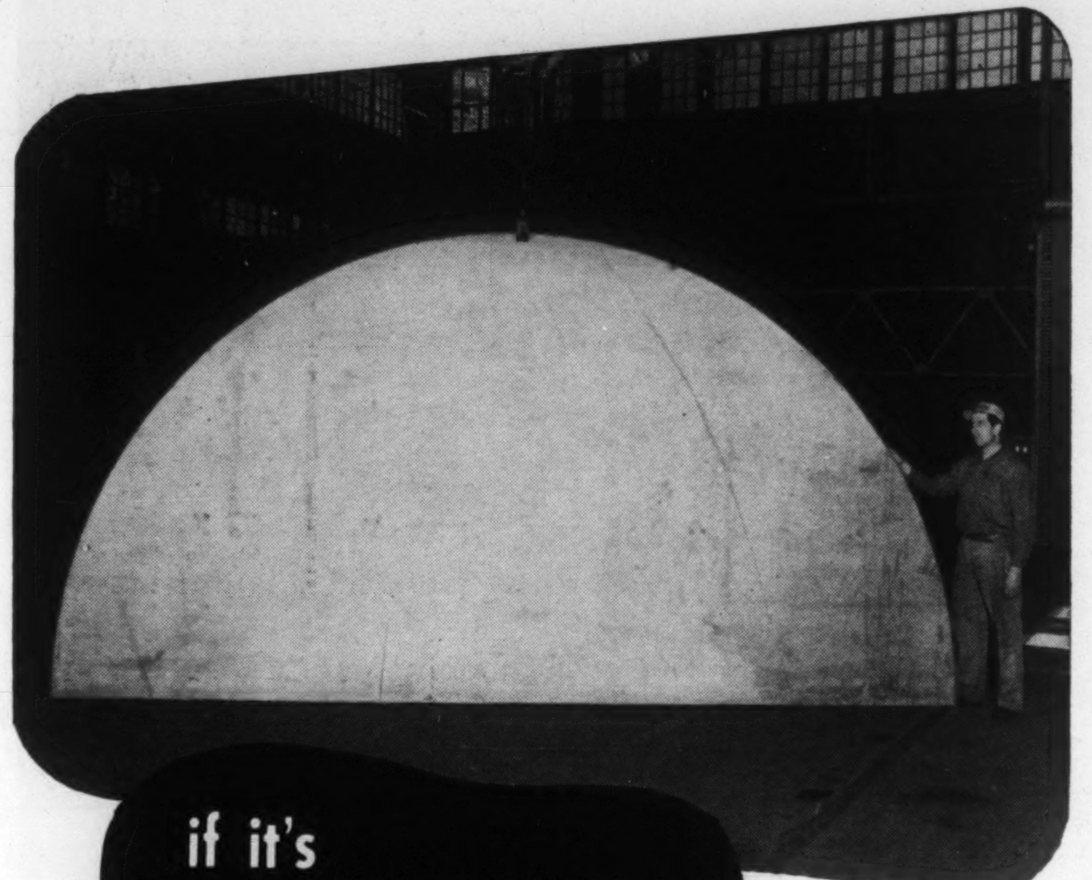

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The segment of a tank head illustrated is typical. Made of 1" thick, Type 302 stainless steel, the head blank measures 210" in diameter and weighs approximately 9900 pounds. So accurately was this segment produced that no "truing up" of the abrasive cut straight edge was required prior to welding two segments together.

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continued from page 178

scopic solid which cannot be fed directly into a reduction chamber at a controlled rate, but must be purified to form a dense salt.

Improvements in the process were described which reduced the previous zirconium tetrachloride purification and magnesim reduction from a two-step process requiring a total time of 60 hr to a combined one-step operation requiring only 40 hr. The resultant mixture of zirconium, magnesium chloride and excess magnesium is vacuum purified, and the sponge thus obtained is ground to chunks and blended into 70-lb batches. Each batch from the reduction process yields about 160 lb of zirconium. Several of these batches are combined to make a blend of 30 batches of 70 lb each. These batches are then used for the melting process.

Melting of Zirconium

The newest consumable electrode arc melting techniques were described by H. L. Gilbert, of the Bureau of Mines. These methods have made obsolete the previously used split tube graphite resistor furnace and the tungsten-tipped electrode arc furnace. Shortcoming with the former was the pick-up of about 0.1 to 0.2% graphite, and the latter resulted in ingots containing heterogeneous tungsten impurity.

The blended sponge zirconium is compacted at 50 tons per sq in. into 2- by 2- by 20-in. electrodes. These electrodes are charged into the closed arc furnace, which is operated under an 80% helium and 20% repurified argon atmosphere. The electrodes are welded together through gloves and are fed into the arc by drive rolls. The power pick-up is supplied by secondary rolls. The molten zirconium is collected in a water cooled copper crucible. Ingots as large as 8 in. in dia weighing 200 lb are now produced, and it is expected that the equipment can be utilized to produce ingots up to 16 or 18 in. in dia without difficulty. The melting rate is about 5 lb of metal per min., and up to nine 100-lb ingots have been produced in 24 hr in one of the arc melting units.

Fabrication of Zirconium

Considerable advances have been made in the fabrication of zirconium, as described by R. F. Gordon, of

(Continued on page 182)

"WAUKESHA METAL" and
WAUKESHA STAINLESS STEEL
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from A to Z
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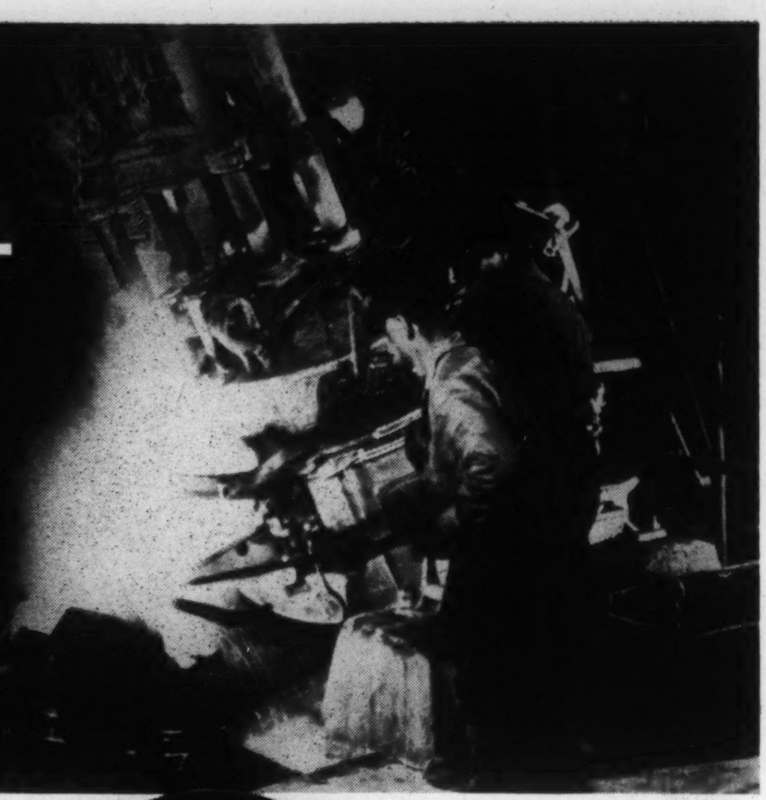

"Waukesha Metal" is a high nickel alloy — close-grained with excellent corrosion-resistant qualities. Waukesha Foundry produces castings in "Waukesha Metals" in a wide range of alloys —

- **for contact with over 100 foods, beverages, chemicals, pharmaceuticals and other products possessing corrosive characteristics.**
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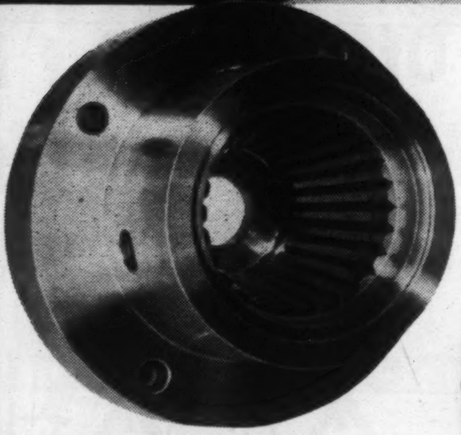
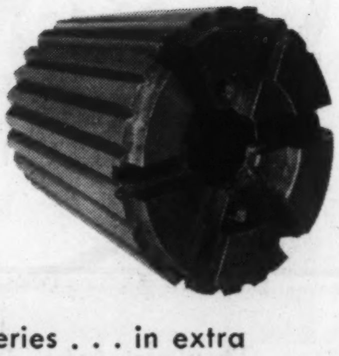
Castings in "WAUKESHA METAL" are so widely used that WAUKESHA is the largest nickel alloy jobbing foundry in the country. As just one example of the industrial acceptance of "WAUKESHA METAL" — virtually all of the milk you drink and all of the ice cream you eat has passed over a "WAUKESHA METAL" casting in processing.





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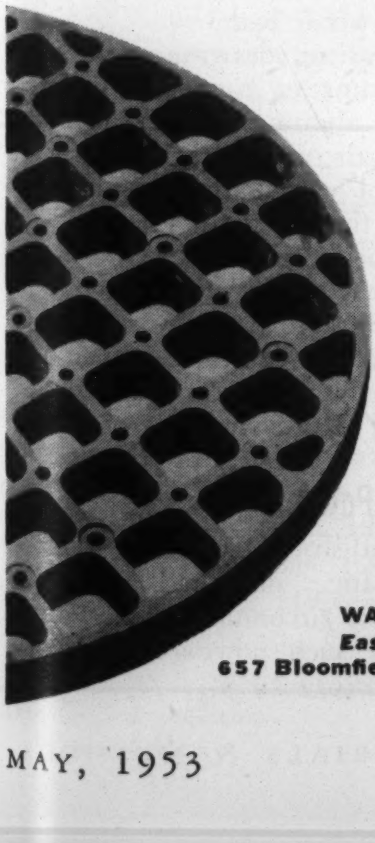
Available in the 300-400 series . . . in extra low carbon and in the 35-15 and 25-12 high alloy series, WAUKESHA offers Stainless Steel Castings that are produced under strict metallurgical laboratory control for close texture, uniformity and dimensional correctness.



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— One booklet on physical properties, chemical specifications and application recommendations of "Waukesha Metals."
— The other booklet on WAUKESHA Stainless Steel Castings describing their metallurgical characteristics and application recommendations.
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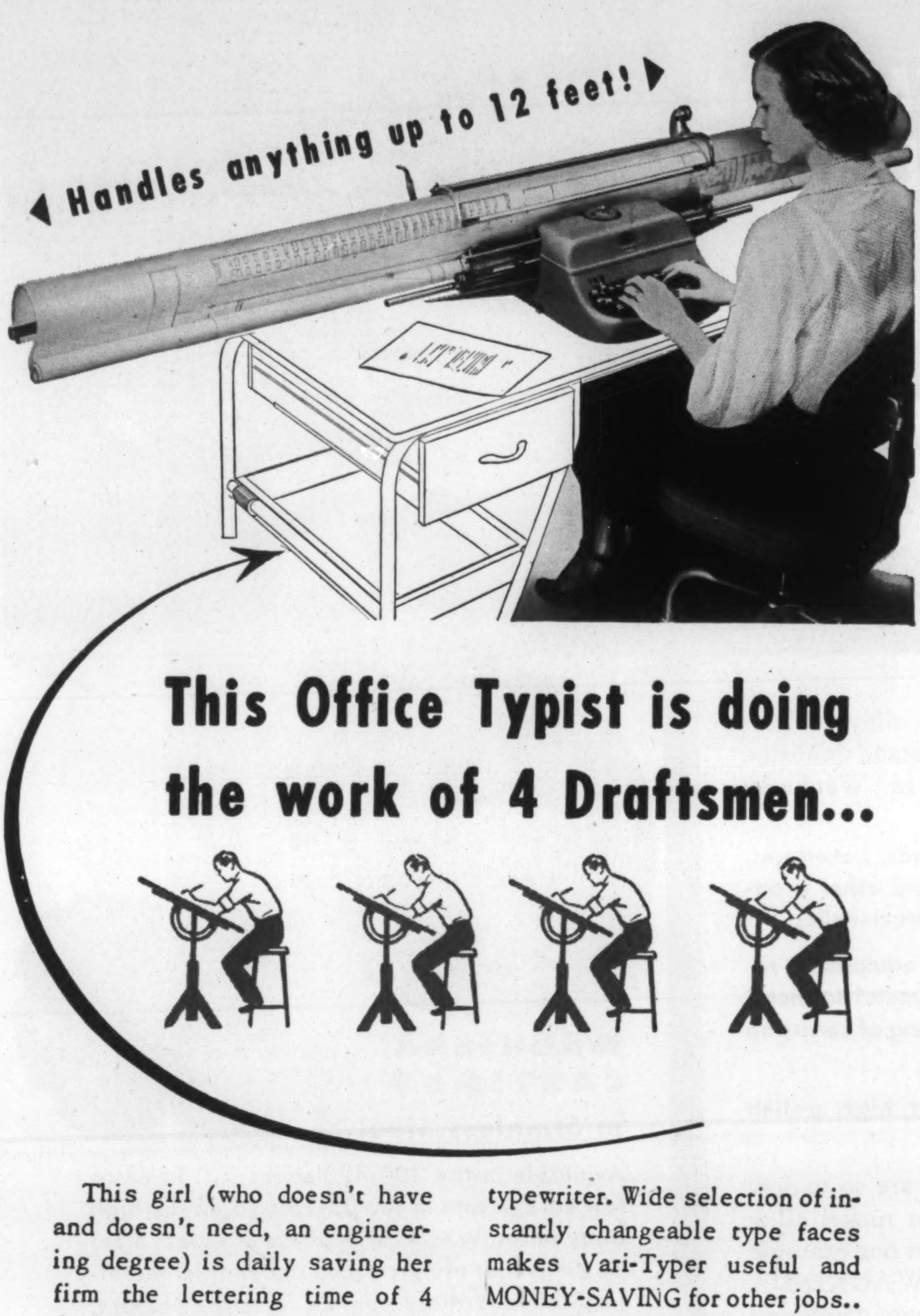

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continued from page 180

the Westinghouse Electric Corp. The chief difficulty is the solubility of oxygen and nitrogen in zirconium. Another is galling, since zirconium acts rather "gummy" in contact with extrusion and drawing dies. Zirconium has been fabricated from zirconium crystal bar by hot extrusion of the bars in a steel or copper can. In addition, hot compacting of pieces of crystal bar in graphite dies at 2900 F and powder metallurgy of zirconium hydride have been useful fabrication methods. These methods are now secondary to the arc melting and subsequent fabrication of Bureau of Mines sponge.

Zirconium is inherently fine grained and is more plastic than mild steel at its hot working temperatures. Hot working yields a tenacious oxide film which is extremely difficult to remove by pickling. Removal of this film is generally accomplished by wire brushing or sand blasting, although a hot nitric-hydrofluoric acid pickle has been reported as successful for removal of the oxide film. Bright etching of the oxide-free surface is accomplished by means of a 50% nitric acid, 5% hydrofluoric acid water solution. Good hot working temperatures are in the range of 925 to 1300 F.

Jacketing of the zirconium in copper or iron sheathing is useful to prevent oxidation during hot working. Such jacketing has also been found useful to prevent seizure in dies during extrusion or drawing. During discussion, both H. L. Gilbert and R. M. Treco described the benefits of an oxide film for drawing of zirconium. This oxide film is best formed in a salt bath.

The shearing, drawing, stamping and machining of zirconium is very similar to aluminum, but in most cases the zirconium results in increased tool wear. Even so, it was concluded that zirconium is an extremely fabricable metal. Annealing temperatures are in the neighborhood of 1300 to 1500 F, and thin shapes must be annealed in either a high vacuum or very pure inert atmosphere to prevent gas pickup.

Zirconium Powder

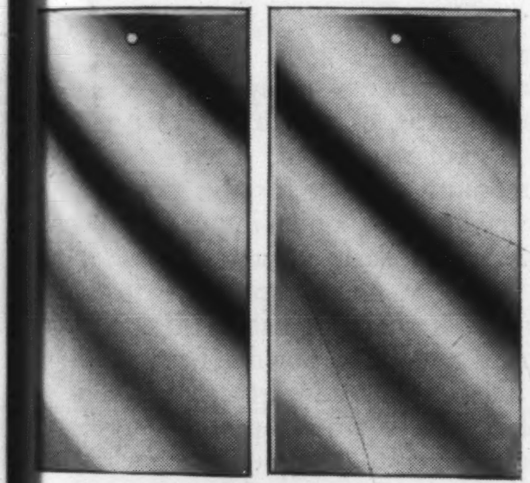
H. S. Kalish, of Sylvania Electric Products, Inc., described methods used to make zirconium powder, and the uses of such powders. One of

(Continued on page 184)

Advertisement

Clear Lacquer Stands Salt Spray Tests for Unusual Periods

Tests conducted by an unbiased laboratory demonstrate that a transparent lacquer, already widely known for its remarkable adhesion to practically all commonly used metals, has the added advantage of exceptional durability. In these tests, the lacquer, produced by Maas & Waldstein Co. and sold under the trade name of DULAC Clear Universal Lacquer #462, was subjected to salt spray and weatherometer tests for exceptionally long periods. No sign was observed either of finish failure or of discoloration of the metal.

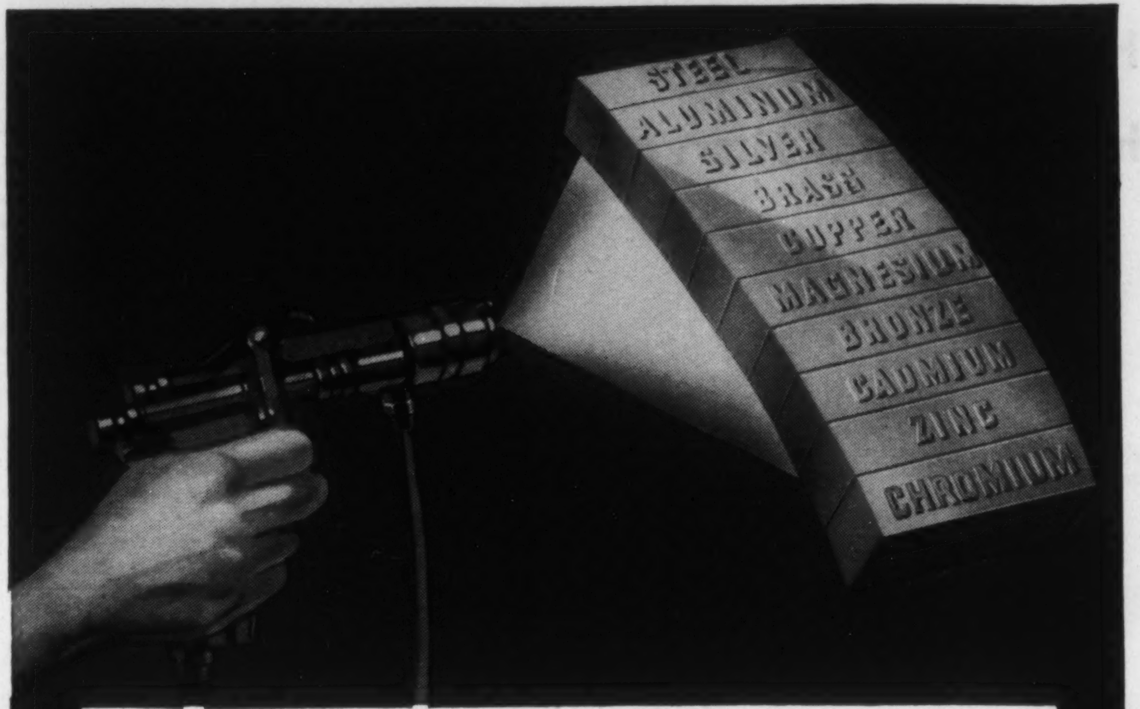


(Left) A zinc-coated steel panel newly coated with DULAC No. 462.
(Right) A similar panel after hundreds of hours' exposure to salt spray, showing no evidence of attack on the finish.

Typical Applications

This unusual durability of DULAC Clear Universal Lacquer #462 has led to its extensive use as a replacement for chromium or other metals normally plated of zinc or zinc-plated steel. An additional important field of application lies in the protection of chromium which because of metal shortages is being plated directly over steel, without the customary underplating of nickel-over-copper.

An air-drying coating, DULAC #462 is easily applied by dip or spray. It dries out of dust in 5 to 10 minutes, and hard in an hour. Technical Data Bulletin #110 in DULAC #462 is available from Maas & Waldstein Co., 2121 McCarter Highway, Newark 4, N. J. On request M & W Technical Service Engineers will discuss specific problems.



ADHERES

to almost any metal

INVISIBLE

on all of them

DULAC Clear Universal Lacquer #462

Here is a *single* water-white lacquer with remarkable adhesion to practically *all* metals. It's DULAC Clear Universal Lacquer #462.

Finishing shop after finishing shop* reports that this M & W lacquer can be applied with *equal* success to just about any metal—and that it's invisible when applied.

AND . . . tests conducted by an unbiased laboratory show that DULAC #462 withstands salt spray and weatherometer tests for longer periods than ordinary lacquers.

DULAC #462 forms a tough, lasting protective film that resists heat, cold, weather, stain, perspiration. It cuts down on *inventories*, because one lacquer handles so many metals. It cuts down on *production time*, because it dries out of dust in 5 to 10 minutes . . . hard in an hour. Applied by spray or dip.

*Names on request

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Because liquid cyaniding of small parts for their famous heavy duty trucks meant high labor costs, International Harvester was looking for a more efficient method of case hardening. Their metallurgists decided that carbonitriding would provide the answer, and with the help and advice of the Armour Ammonia Technical Service Department they had the necessary equipment installed.

The change was even more successful than they had hoped. International's Fort Wayne plant reported lower labor costs, as expected, in carbonitriding thrust washers, shifting forks, brackets, miscellaneous pins, and similar small parts. They also found that carbonitriding's circulating gases assure a more uniform case on intricate parts. And carbon and nitrogen concentrations are more accurately controlled, resulting in fewer rejects. Finally, working conditions were much improved.

Carbonitriding has been proved in plants of many other companies. It has reduced costs and increased safety. In many cases Armour men have given advice and help on installations. This help and advice is just part of Armour's service to our ammonia customers. Since 1947 Armour has sponsored a fellowship at Massachusetts Institute of Technology for the study of carbonitriding and other similar metal treating processes. This knowledge is from basic research, and available to everyone. Perhaps even more important, the men of Armour's Technical Service Department are equipped to handle and answer any problem arising with ammonia installations for metal treating. The booklets offered below will show you how to put this knowledge to work for you. Write today for your free copies. And, if your problems are unusual or pressing, write giving full details of your requirements.

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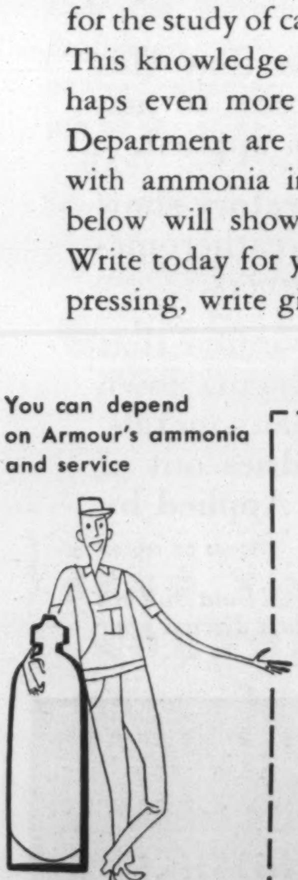

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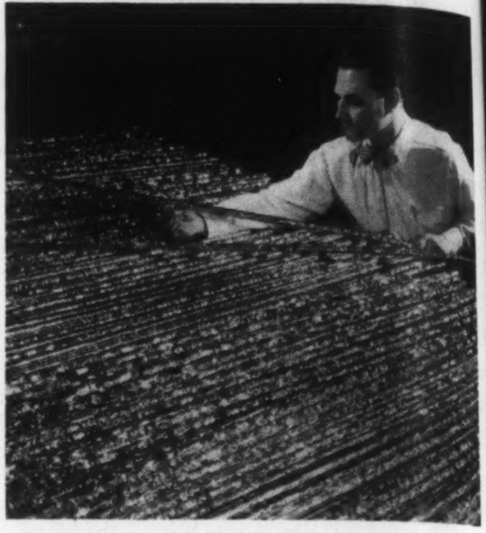

Slightly lighter than steel and having the lowest nuclear cross-section of any known structural metal, zirconium will play a major role in nuclear powder development.

the most important uses for zirconium powder today is in photoflash lamps, of which over 350 million are produced a year. The zirconium powder for this use, however, must be quite impure to give the proper flash characteristics.

Of very great importance to the future is the preparation of a high purity zirconium powder from which a ductile sintered part can be fabricated. This would permit powder metallurgy to supplement melting techniques in the fabrication of parts for zirconium's potential use in nuclear reactors and in the chemical industry. Two methods are presently available for making zirconium powder of good purity for such usage. These are the hydride process and the calcium reduction of zirconium oxide. It was predicted, however, that an even more economical method for producing a much purer zirconium powder would be developed when the need arises.

The safety measures required for the handling of the potentially pyrophoric and explosive zirconium powder were emphasized.

Corrosion Resistance of Zirconium

Of very considerable importance is the corrosion resistance of zirconium. While the matter came up throughout the discussion of the three-day symposium, the subject was given a formal presentation by L. B. Golden, of the Bureau of Mines, who is studying the corrosion of both zirconium and titanium in acid and chemical media. In general, the

(Continued on page 186)

Wha-at! *Cleaner* than a hound's tooth?

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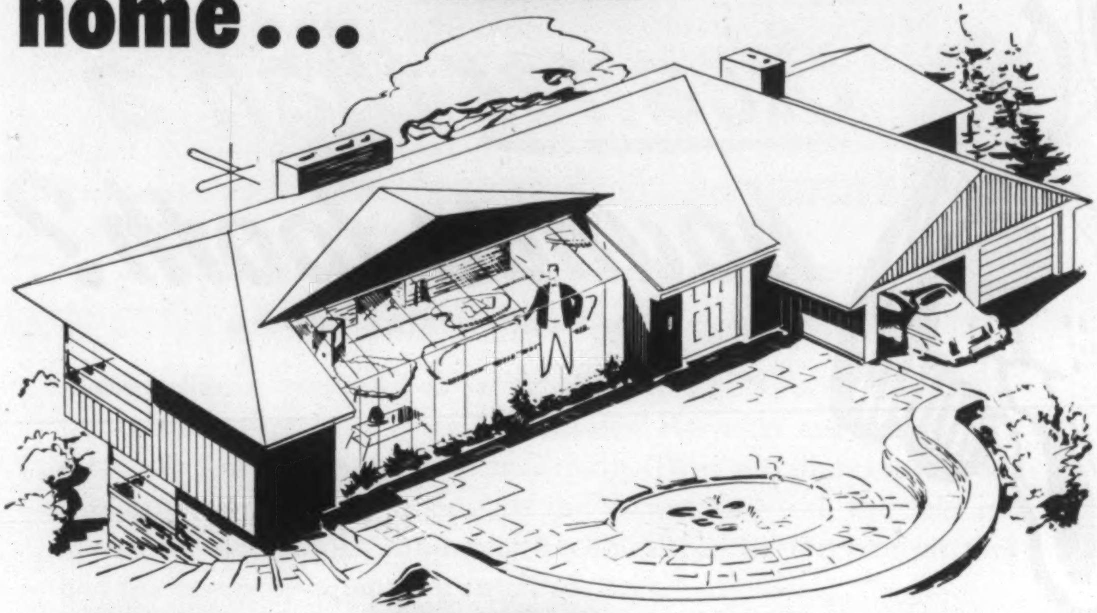
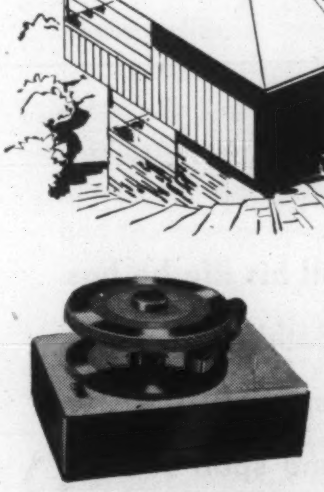
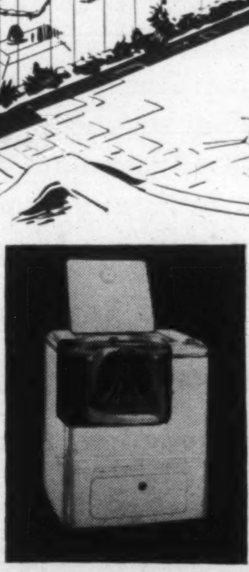



DIMENSIONAL STABILITY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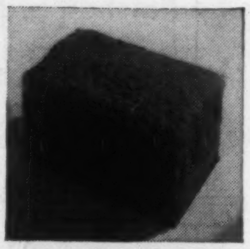
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PHENOLIC PLASTICS THAT FIT THE JOB

Zirconium . . . .

continued from page 184

corrosion resistance of zirconium is slightly better than titanium, and in many media they are both considerably better than stainless steel. In the future, such things as cooking utensils and household kitchen uses to replace stainless steel were considered quite likely.

Specific chemical corrosion is of interest. It was found that above 212 F the corrosion resistance of zirconium in phosphoric acid decreases considerably, but below 212 F the corrosion resistance was very good. The addition of 13 wt percent zirconium to titanium improved the corrosion resistance 200 times in phosphoric acid. Zirconium is superior to stainless steel in many corrosive media, such as ferric chloride and copper chloride solutions, and hydrochloric acid. In the former two media, however, some embrittlement occurs. In concentrated hydrochloric acid, zirconium has excellent corrosion resistance, but for some acid applications, such as nitric acid, the new metal may not be suitable.

Physical Metallurgy of Zirconium

According to W. L. Mudge, Jr., Westinghouse Electric Corp., zirconium, and zirconium-tin alloys (up to about 5 wt percent tin) are inherently ductile down to liquid nitrogen temperatures. A slow cool from 1200 F, however, often renders the material brittle in notch impact. A water quench from perhaps 1800 F, on the other hand, renders the metal ductile in notch impact tests. It was found that this brittleness is caused by the precipitation of zirconium hydride on slow cooling and that the small quantities of hydrogen responsible for this effect can be kept in solid solution by quenching from high temperature. As little as 10 ppm of hydrogen was found to have some effect on the notch brittleness. In general, it was stated that a slow cool from above 500 F causes embrittlement and a quench above this temperature renders the metal ductile when the hydrogen content is in the range of about 0.001 to 0.010 wt percent.

It was said that precipitation of the hydride occurs over a very narrow range of temperature above 500 F. The hydrogen can be re-

(Continued on page 188)

ON MINNEAPOLIS-MOLINE'S UNI-HARVESTOR...

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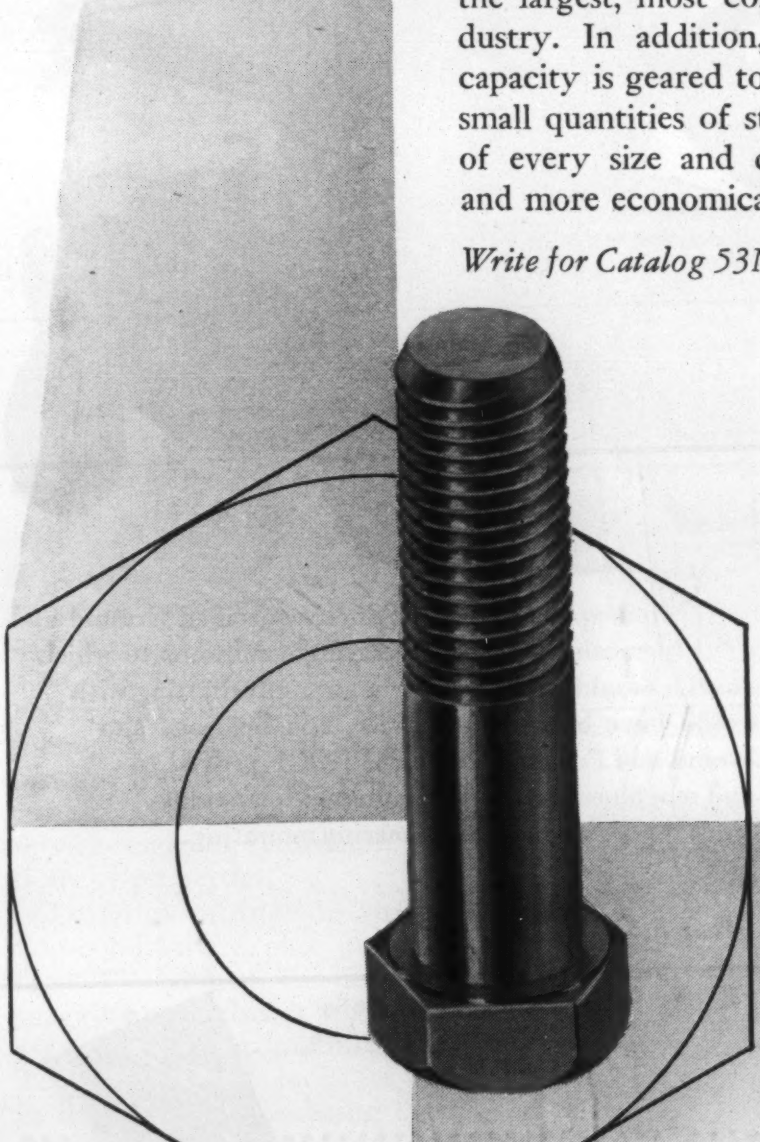


ANTI-CORROSIVE METAL PRODUCTS CO., INC.

Castleton-on-Hudson
New York

Zirconium . . . .

continued from page 186

moved by annealing above 1475 F in a very good vacuum.

Information was reported on improved analytical techniques such as the hot vacuum extraction method for hydrogen. Metallographic techniques are rapidly improving also for zirconium and titanium.

Throughout the symposium there was discussion on oxygen pick-up and the effects of oxygen. This matter had been given a systematic study by R. M. Treco, Bridgeport Brass Co., who said that up to about 0.2 wt percent oxygen sufficient ductility remained in zirconium to cold roll it 70%. At 0.4 wt percent oxygen, however, the metal becomes very brittle. Some oxygen seems to be beneficial in strengthening zirconium, but the strength gained by oxygen additions is lost at temperatures above 750 F. Thus, oxygen-bearing zirconium can be hot worked as readily as the very high purity material, and the addition of oxygen can be used to strengthen zirconium at temperatures up to about 650 F.

Several zirconium phase diagrams have been studied, including zirconium-silicon, zirconium-tin, zirconium-nickel and zirconium-manganese, which were presented at the Western Metal Congress. It would seem that the metallurgy of zirconium is rapidly taking its place along with the other well known metals.

The complete series of papers which made up this zirconium symposium is to be published in the near future in book form by the American Society for Metals.

Now
U. S. DEFENSE BONDS
EVEN BETTER

News Digest

Magnesium Industry . . . .

Continued from page 7

tempt to educate designers, engineers and potential users as to the value of the metal and thereby expand its usage, particularly in civilian applications.

Uses Displayed

Among the consumer items displayed were chairs, ladders, typewriters, vacuum cleaners, portable radios, sewing machines, cameras, skids, boats and movie projectors. Other prominent applications were beer crates, textile machinery parts, printing plates, power tools, portable x-ray machines and gasoline tanks.

More than a third of this country's magnesium production is believed to be going into the transportation field. At the show, there were magnesium truck bodies, helicopters and aircraft parts and engines. Attracting most attention was the 132-lb all-magnesium automobile body designed and built in England.

Half the space at the show was devoted to military applications. In addition to the aircraft applications mentioned above, there were radar trailers, electronic systems, artillery pieces, ammunition components, and many other items developed by the various technical branches of the armed services.

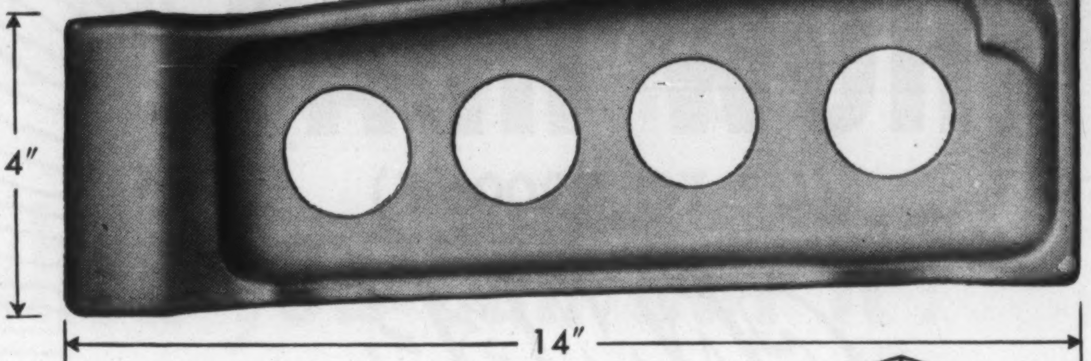
Several exhibits demonstrated the fabrication characteristics of magnesium. Drawing, welding and finishing were performed on the exhibition floor.

Engineers Short

The nation's industrial recruiting agents this year will be trying to uncover 25% more engineers than they were able to find last year. Last year, they fell short of their goal by more than 30%, according to a report by Frank S. Endicott, director of placement at Northwestern University.

Whether they will do any better this year is doubtful. Although about 23,000 men will receive baccalaureate degrees in engineering this year, it is estimated that 75% of them have had no prior military service.

Many positions will be filled, how-



From Jet Bomber Parts to Gas Range Burners

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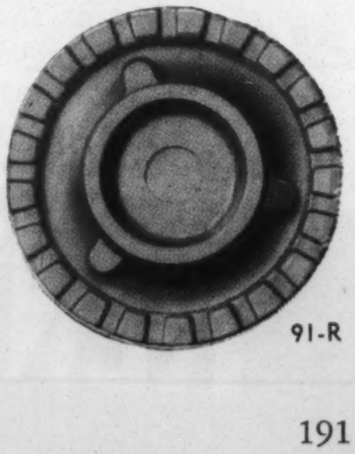

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HOW HEAT

(UP TO 2200° F)

CAN BE STOPPED COLD

Destructive effects of extremely high temperature can be minimized—by using Kentanium at the critical points.

WHAT is Kentanium?

Chiefly titanium carbide (and small percentages of other refractory metal carbides), with nickel "binder". Uses neither tungsten nor cobalt. Hardness: Up to 93 RA. Weight: ⅔ that of steel.

WHAT can it do?

Resist thermal shock, withstand oxidation and abrasion, retain great strength at high temperatures (1800°F and above).

WHERE is it in use?

Successful applications include: Valves, valve seats, reduction crucibles, anvils for spot welding, hot extrusion die inserts, bushings, thermocouple protection tubes, flame tubes, furnace tong tips, balls for hot hardness testing, nozzle vanes and blades for jet engines, and many others.

WHAT forms are made?

Tubes, rods, bars, flats by extrusion process. More complex parts by machining from pressed slugs before sintering, extremely accurate parts by grinding to required tolerance after furnace sintering.

HOW can you use it?

This remarkable new metal, available in many "grades" to meet specific combinations of imposed conditions, can best be adapted to your high temperature problem by cooperative effort. Our engineers will be glad to discuss how you can get best results from Kentanium.

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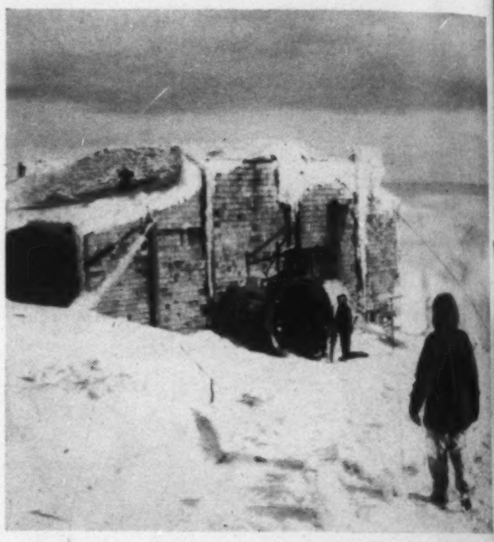
KENTANIUM

HEAT-RESISTANT, HIGH-STRENGTH, LIGHTWEIGHT
CEMENTED TITANIUM CARBIDE

ever, by engineering college graduates leaving the armed forces. Placement of these men is being expedited by organizations formed by GI engineers in various military research and development stations for that very purpose. These efforts are expected to be supplemented by a placement campaign conducted by the Engineering Manpower Commission of the Engineers Joint Council.

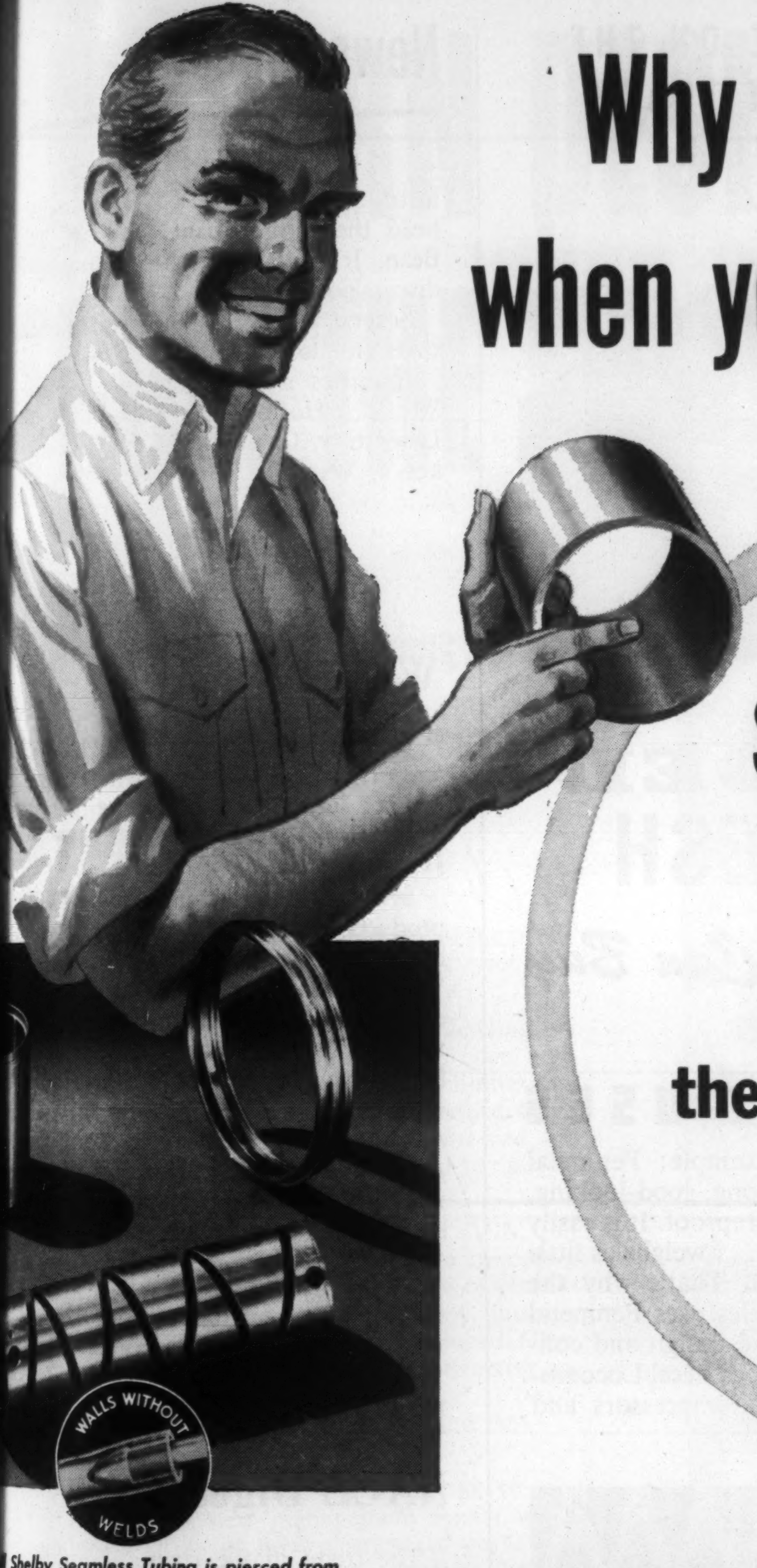


Simulated Service Testing can be carried to chilly extremes. A good example is this Mt. Washington laboratory above the clouds where aircraft gas turbine engineers conduct intensive icing tests on military jet power plants under conditions which closely simulate those encountered by jet engines in service. The 6240-ft summit of Mt. Washington in New Hampshire has known wind velocities of 230 mph and temperatures as low as –46 F. (Courtesy General Electric Co.)

Stress Analysis

New techniques in stress analysis will be unveiled at the spring meeting of the Society for Experimental Stress Analysis, to be held May 20 to 22 at the Hotel Schroeder, Milwaukee, Wis.

Regular morning and afternoon technical sessions will be held on Wednesday, May 20, and Friday, May 22. Thursday will feature two panel discussions, one on fatigue techniques and evaluation, and the other on strain gage techniques and



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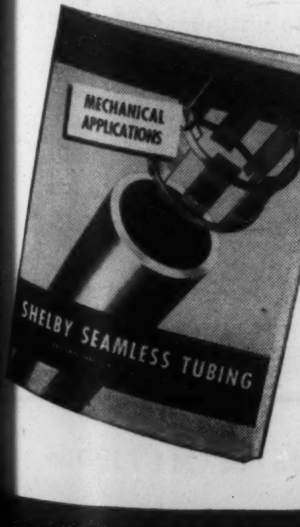

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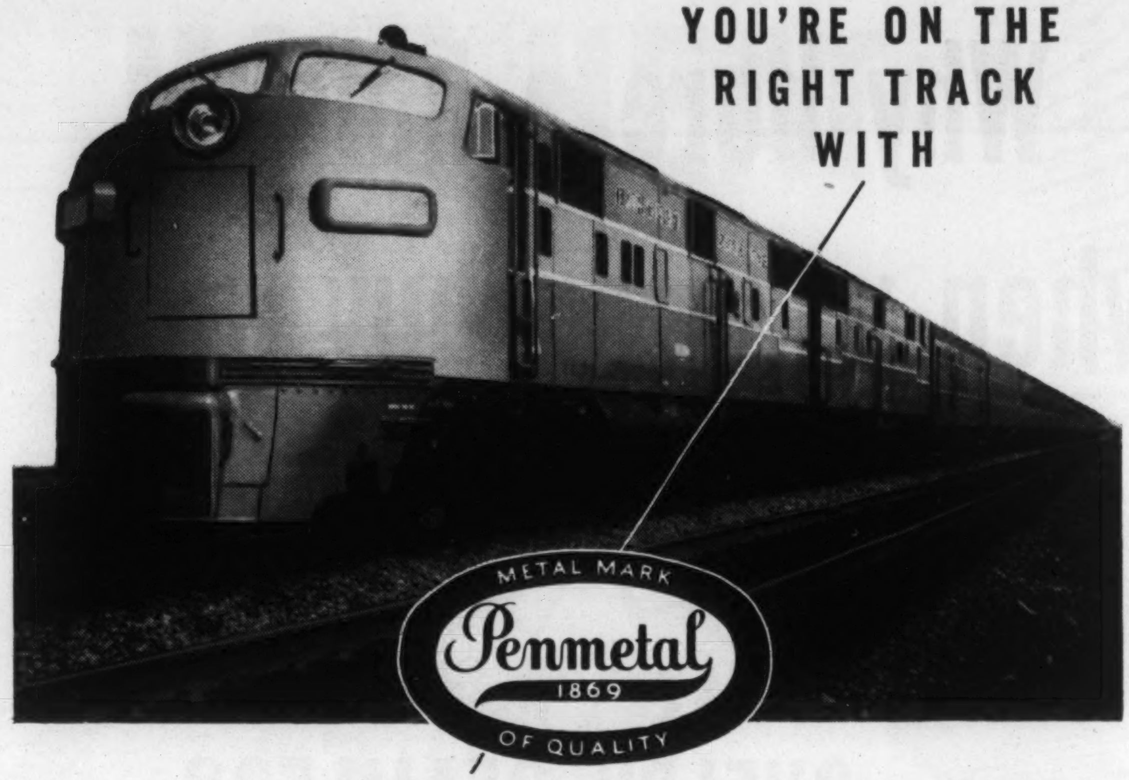

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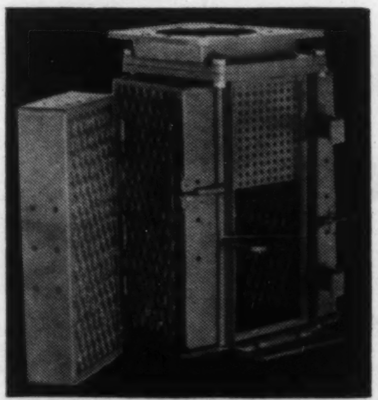

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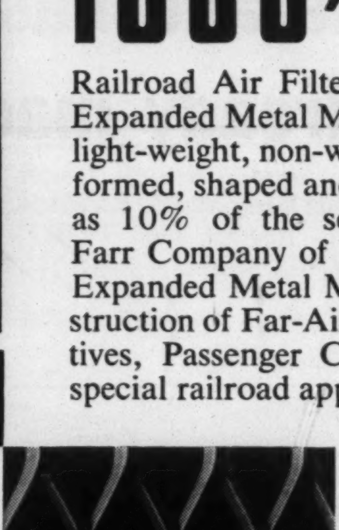

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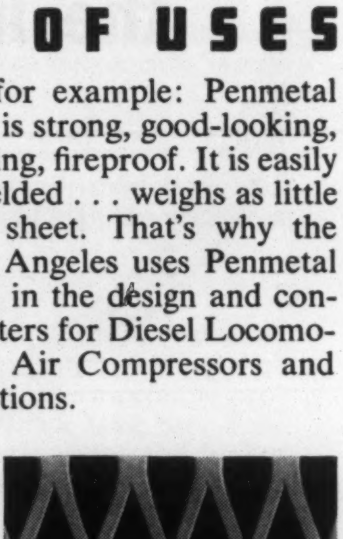

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News Digest

instrumentation. J. T. Dolan will head the fatigue panel and W. T. Bean, Jr. will direct the strain gage discussion.

Several plant trips and social occasions are also scheduled.

Inquiries should be addressed to W. F. Hofmeister, Metallurgical Laboratory, Chain Belt Co., Milwaukee 4, Wis.

Welding Show

Latest developments in welding and its allied processes will be on display June 16 to 19 at the Shamrock Hotel Hall of Exhibits in Houston, Tex.

Seventy manufacturers who sell products to the welding industry will be represented in the American Welding Society's first all-welding exposition, to be held in conjunction with its spring technical meeting. Products for welded fabrication, weldments, welding processing, gas cutting, brazing, finishing, tooling, gaging, testing, stress relieving, x-raying, servicing and handling will be exhibited and demonstrated.

Fighting Corrosion: NACE Digests

The trend in the chemical industry toward higher operating temperatures and pressures has presented the equipment designer with fresh problems. One of the biggest is the lack of corrosion data for various chemical solutions at temperatures above their normal boiling points.

As a result, some of the most important corrosion studies today are those dealing with the resistance of various engineering materials to such solutions. Two papers on this subject were presented at the ninth annual conference of the National Association of Corrosion Engineers, held at Chicago in March.

Other papers of particular interest, which are mentioned below, covered the oxidation resistance of boron-containing chromium-nickel-cobalt-

MODERN DESIGNS BENEFIT FROM THE NEWS IN PLASTICS

Raw materials and molding techniques have wrought changes in design and production

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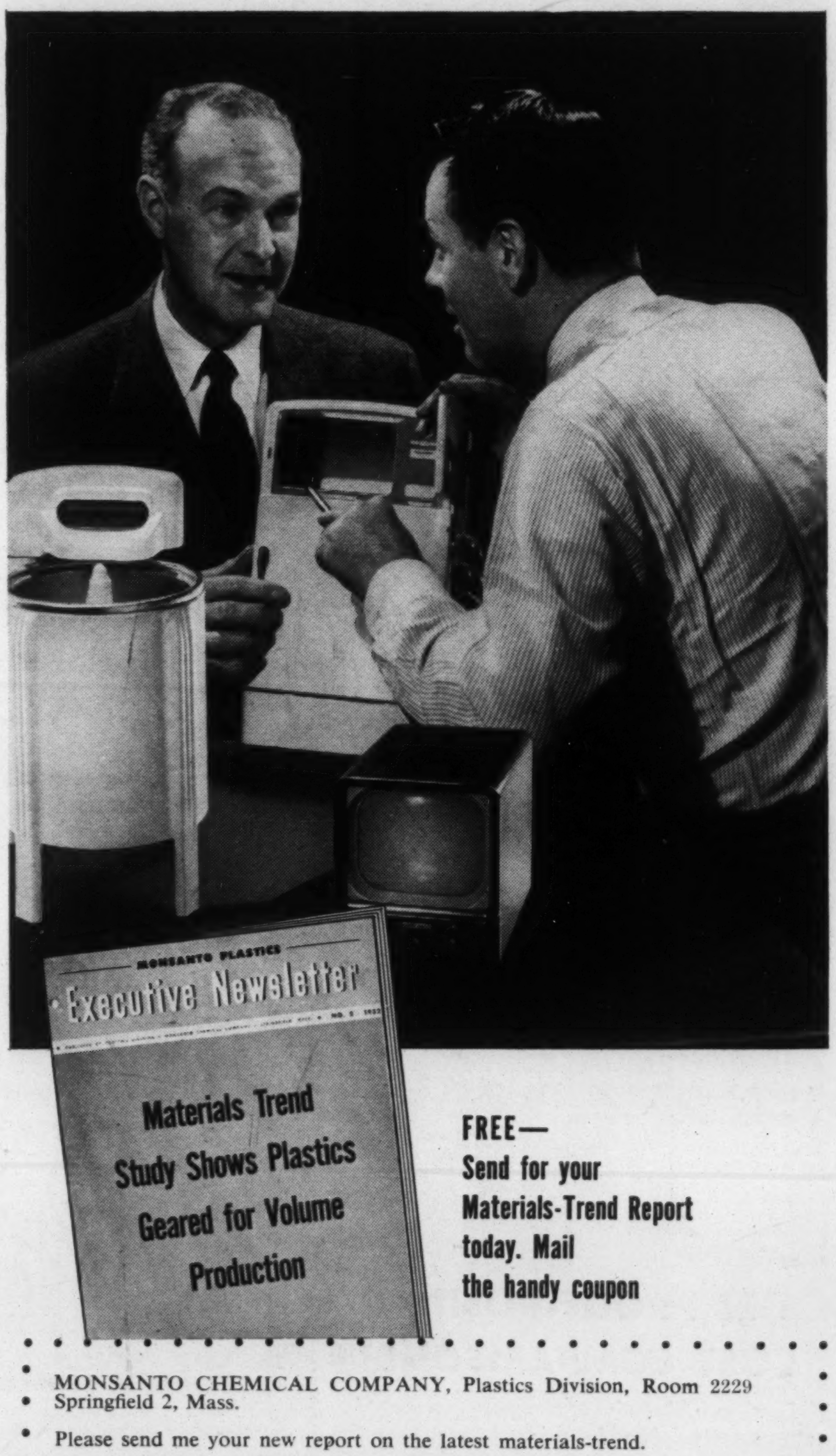
For more information, you are invited to send for Monsanto's new management report which includes a study of how plastics are geared for volume production of large parts today. The coupon is for your convenience. For individual assistance with your problem, call on the Monsanto Technical Council—a board of experts in plastics at your command.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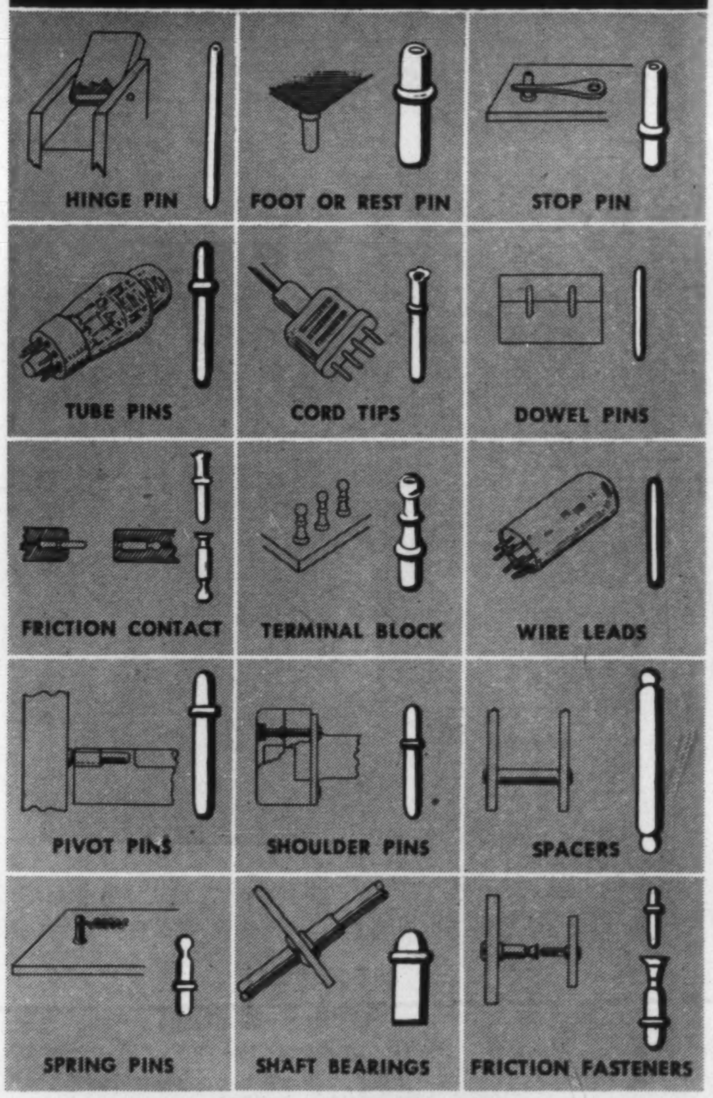

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News Digest

iron alloys, the effect of weld seam and weld flux on metal surface and coating life, and the effects of the composition of steel on performance of organic coatings in atmospheric exposure.

Hot Solution Attack

F. H. Beck and M. G. Fontana, of Ohio State University, investigated the corrosion of a variety of metals and alloys by nitric, phosphoric, acetic and surfuric acids and sodium hydroxide at temperatures up to 425 F. The metals included 18:8 stainless, 18:8 stainless with molybdenum, Durmet 20, 18% chromium steel, cast iron, nickel, titanium, Duriron, and some of the very high alloy materials.

In general, they found corrosion increases rapidly as the temperature is raised above boiling, and in some cases extremely rapid and unexpected attack occurs. On the other hand, spectacular decreases in corrosion rates were observed in some cases where an inhibiting metallic ion was introduced. An example is the effect of copper ion on the corrosion of stainless steel by phosphoric acid.

A report by R. F. Miller, R. S. Treseder and A. Wachter, of Shell Development Co., also included similar data on the action of formic acid, boric acid and phenol. Both papers described the equipment and methods used for high-pressure corrosion testing.

Effect of Boron

In the course of tests on high temperature materials, W. O. Binder, of Electro Metallurgical Co., and E. D. Weisert, of Haynes Stellite Co., subjected a series of alloys containing 18 and 20% chromium with various balances between nickel, cobalt, iron and boron to oxidation in air at temperatures of 1650, 1830 and 2012 F. They found that chromium and nickel increased oxidation resistance, while iron, boron, and, to a lesser extent, cobalt had an adverse effect. Molybdenum greatly decreased oxidation resistance. Carbon and tungsten appeared to have no effect in these alloys. The tests were designed particularly to indicate the effect of the boron. Despite its adverse effect, the authors concluded that boron-bearing alloys could be designed which would have oxida-

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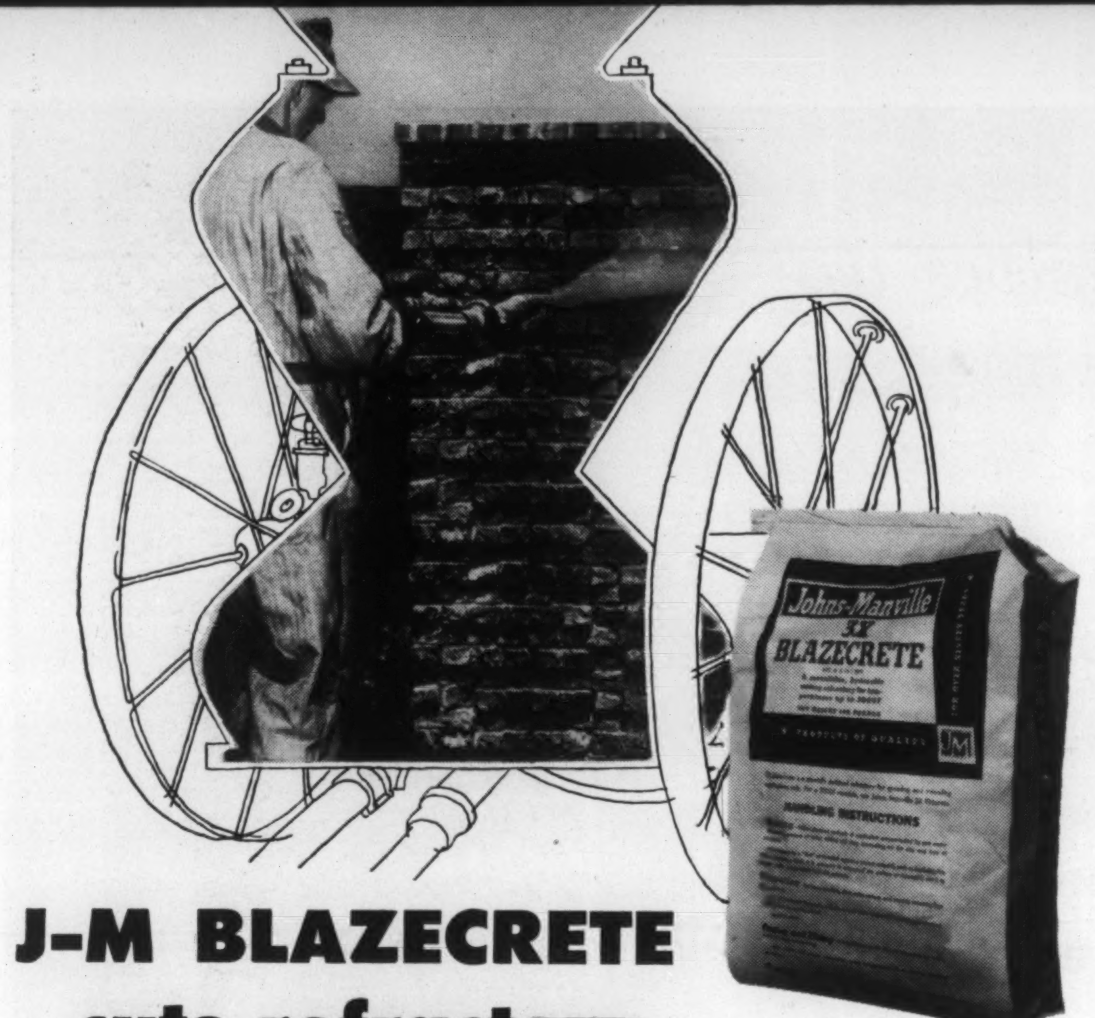

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That's why it pays you to use this hydraulic-setting refractory for temperatures to 3000F

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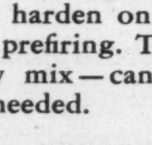

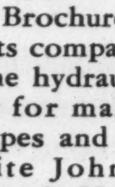

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tion resistance comparable to those without boron. This could be done primarily by keeping iron content below 6% and by using tungsten rather than molybdenum as a minor addition for strengthening.

The problems involved in getting a good protective coating on a weld seam were pointed up by A. J. Liebman of Dravo Corp. The important difference between clean steel and average weld seams, he said, is the presence of interference products in the form of weld flux slag and weld flux fume dust deposits on the weld seam and to within several inches of it.

He mentioned specifically:

1. Harmful coating deposit variations caused by disturbed mill scale and by the peaks and valleys that are especially bad on hand welding seams.
2. Alkalinity of the weld flux slag which, in humid environments, causes rusting of the metal and resulting destruction of large areas of paint several feet away by "rust creepage."
3. Brittleness of weld flux slag, which causes slag to separate from the metal, taking the coating with it.
4. Weld flux fume dust, which accelerates corrosion by slag. The paper described the use of primers, mastics, wetting oils, chemical treatments, surface preparation and prewelding compounds and their effects on weld seam protection in various environments.

Coatings on Alloys

At least a partial answer to the question of whether the improved atmospheric corrosion resistance of alloy steels is of any advantage when they are painted was found by F. L. LaQue, of The International Nickel Co., Inc., and J. A. Boylan, of Parker Rustproof Co. The steels they tested showed a 20:1 spread in corrosion resistance between an exceptionally low-copper ingot iron and a typical low alloy, high strength steel.

The paint system used was a common automobile finish—a pigmented baking alkyd primer with pigmented baking urea modified alkyd top coats, with and without zinc phosphate (Bonderite) pretreatment. Test panels were exposed 80 and 800 ft from the ocean at Kure Beach, N. C., in an industrial atmosphere at Bayonne, N. J., and in a rural

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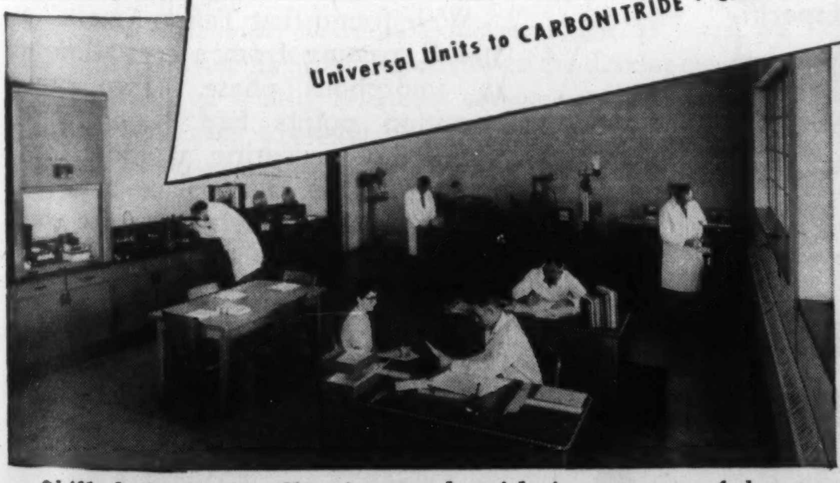

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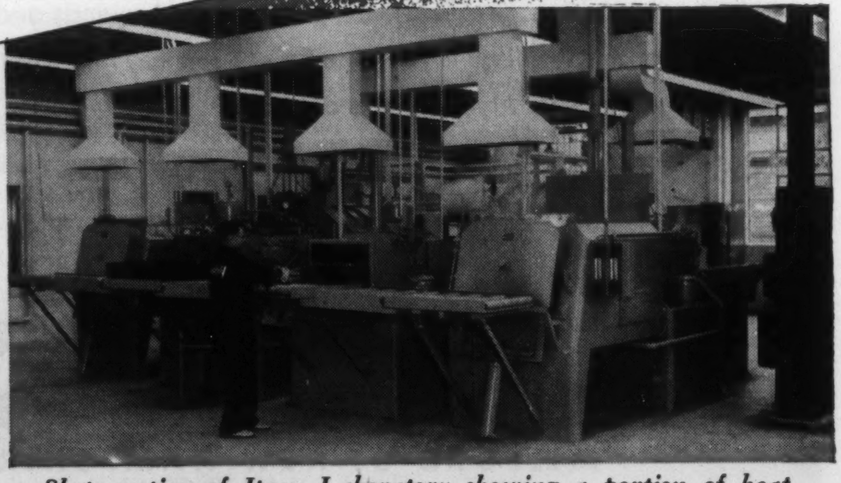
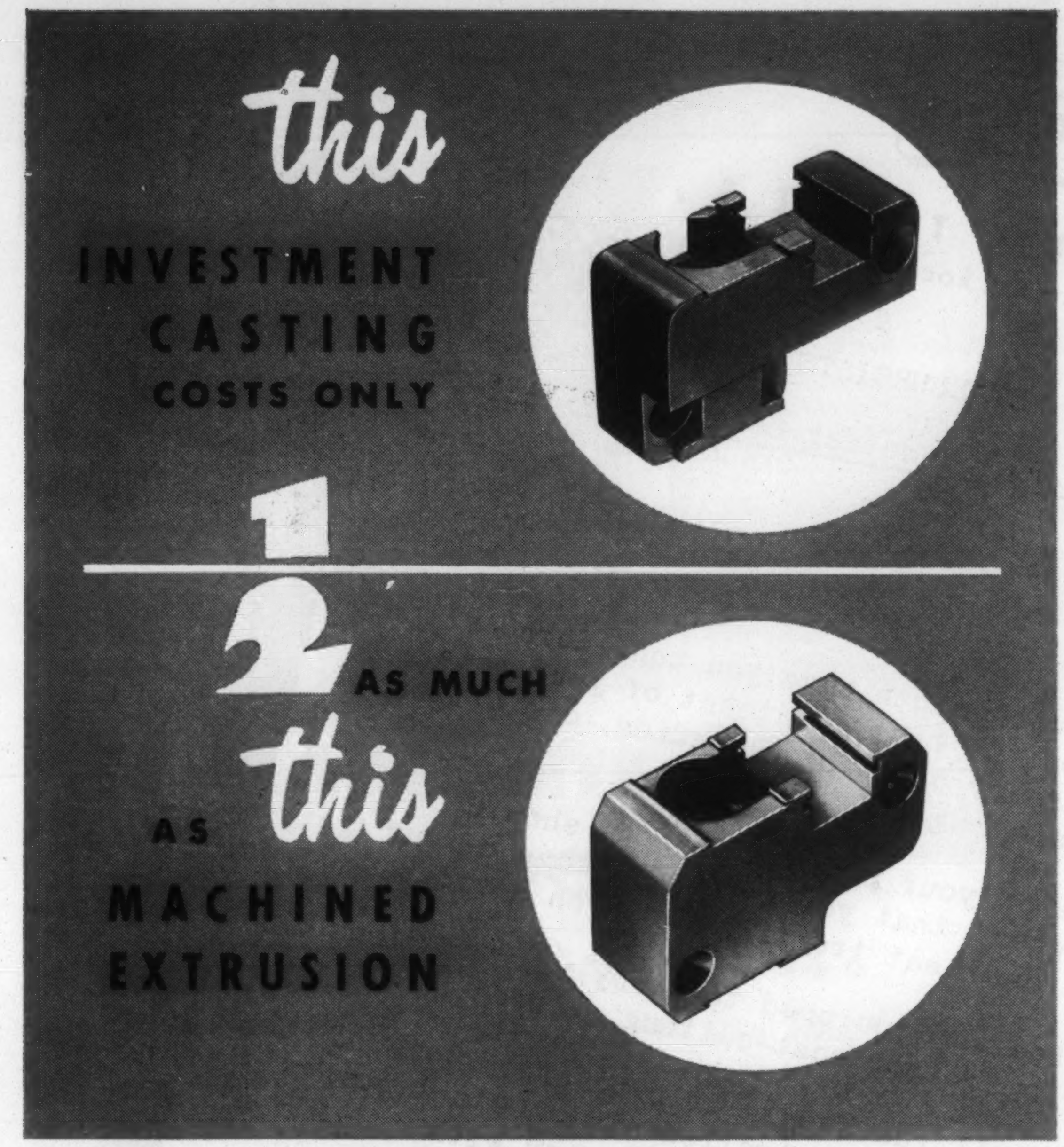


Shop section of Ipsen Laboratory showing a portion of heat treating equipment which includes 250 and 400 lb./hr. automatic controlled atmosphere furnaces, washers, and tempering units.



General Bronze Corporation, Garden City, N. Y., discovered that this Hitchiner-cast window lock housing gives completely satisfactory performance and eliminates the drilling and boring of a half-inch through hole and the milling of slots and dovetail recesses as well as the drilling and countersinking of mounting and set screw holes. In the investment casting only the set screw hole is drilled and tapped.

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atmosphere at Morenci, Mich.

The authors found:

1. The low alloy steel performed best, the copper steel next, and the low copper content open hearth iron was worst whether painted or bare.
2. The zinc phosphate pretreatment improved the performance of all painted steels. This advantage increased with the severity of the atmosphere and with the vulnerability of the steels to attack.
3. The best performance was that of the low alloy, high strength steel with a zinc phosphate pretreatment.
4. Exposure for a few weeks 80 ft from the ocean at Kure Beach was less damaging to bare steel, but more damaging to painted steel, than the industrial atmosphere at Bayonne.

Teflon Changes

Resistance of Teflon to chemical and thermal degradation is well known. Not so well known is its peculiar behavior when certain changes in temperature and pressure occur.

C. E. Weir, of the National Bureau of Standards, has found that Teflon exists in three polymorphic forms within the range from 50 to 175 F at pressures between one and 10,000 atmospheres. The sharp changes in volume occurring at the transition conditions make this information of practical importance where dimensional stability is required.

Weir found that Teflon "melts" at 594 F, passing from a crystalline to an amorphous phase. Two other transition points had been found earlier, both occuring at room temperature. One takes place at 68 F under one-atmosphere pressure and involves about a 1% change in volume. The other occurs at 78 F under 5500 atmospheres (81,000 psi) and involves a 2.5% volume change.

The data was obtained in the course of a continuing study of the effect of pressure on high polymers. So far, Teflon appears to be unique in its behavior under pressure.

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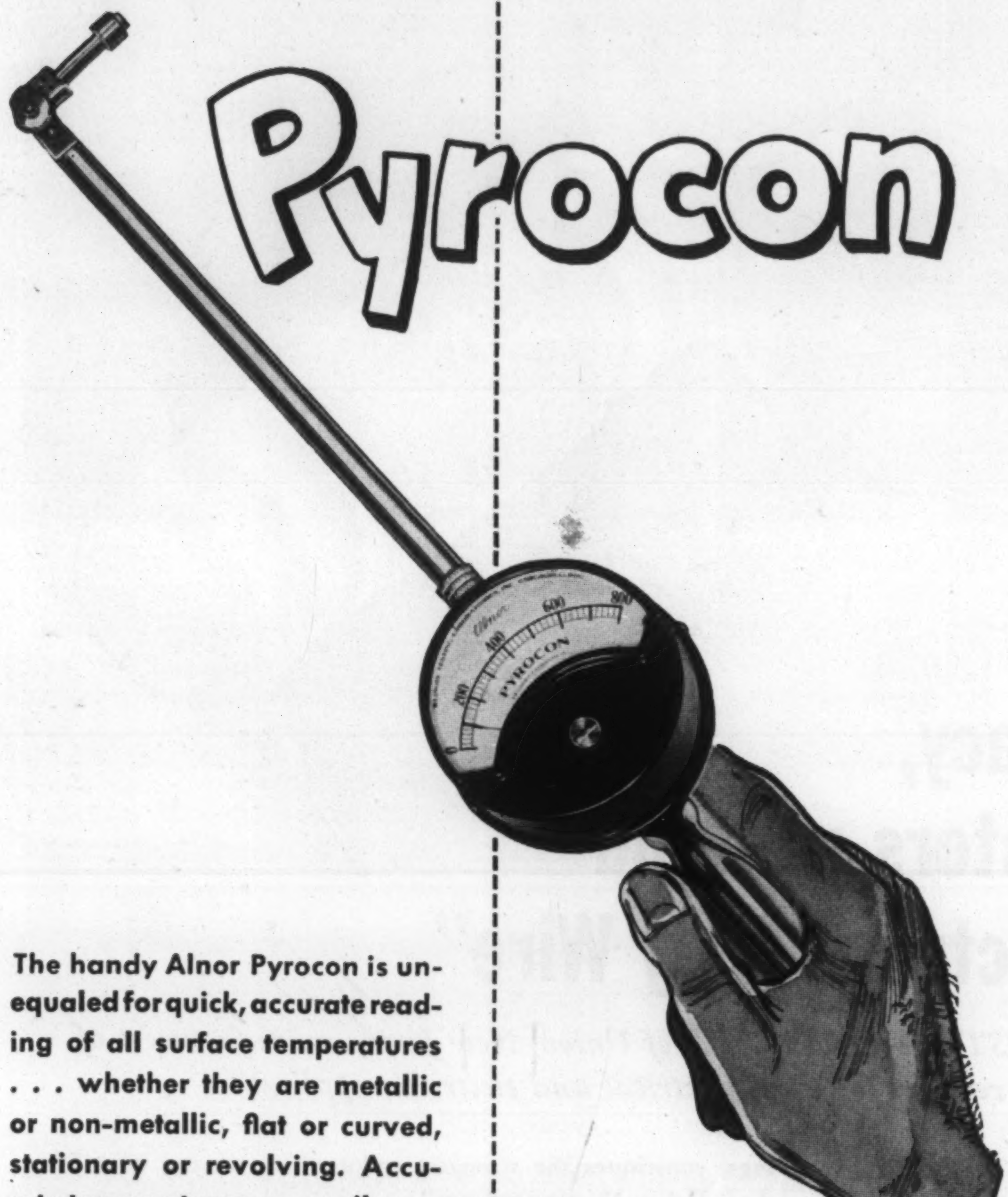

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PRECISION INSTRUMENTS FOR EVERY INDUSTRY

News Digest

Battelle Announces . . . .

continued from page 11

The new alloy was developed by J. H. Jackson, D. B. Roach and R. B. Fischer. Research on a replacement for the copper-beryllium alloys was started at Battelle in 1949 by International Business Machines Corp., which is one of the largest users of the alloys. Possible scarcities of good beryllium-containing ores were anticipated. The country, at that time, was heavily dependent on imports of the material from foreign countries, principally Brazil, South Africa, India and Argentina. The future supply of copper-beryllium alloys was, and still is, critical because of possible large-scale use of beryllium in the atomic energy program.

May Cost Less

According to Battelle, cost of the new alloy is expected to be somewhat less than for the copper-beryllium alloys when manufacture can be put on a mass-production basis. A pound of beryllium metal currently sells for $71.50, as compared to a price for nickel, silicon and aluminum—the substitute alloying agents—considerably below $1 per lb.

The aluminum-antimony compound is one of several that may come from compounds of aluminum, gallium and indium with arsenic and antimony. Rectifiers have already been produced in the laboratory with the new "semiconductor material," and its use in the making of transistors is a distinct possibility, according to Battelle's Dr. A. E. Middleton.

Studies sponsored at Battelle by the Bradley Mining Co. have shown that aluminum-antimony has electrical properties "at least as interesting as those of germanium and silicon". Furthermore, the new semiconductor material may be superior to germanium, and perhaps silicon, for military uses where operation at high temperatures is required.

Also Low in Cost

Aluminum-antimony is also attractive costwise, Middleton says. Both components currently sell at less than 50¢ a lb. Germanium sells for about $350 a lb. Raw material cost, however, is only a small fraction of the total cost of any rectifier or transistor.

Aluminum-antimony has essentially the same simple, diamond-like struc-

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ture as silicon and germanium, except that its framework contains two kinds of atoms. Simple structure greatly facilitates the development of methods for the purification and control of semiconductor materials.

Battelle's work on aluminum-antimony has also shown that this material can act as an electric switch under exposure to light, and can be used to convert light to electrical energy. This suggests possible applications of the compound in photoelectric cells for such uses as automatic door openers and number-counting devices on production lines.

Die Castings: Light Metal Limits

The choice between zinc and a light metal — aluminum or magnesium—for a die casting would be a simple matter if the cost of the metal were the only important factor. Metal cost of a zinc die casting is almost twice that of a die casting of aluminum or magnesium of the same design.

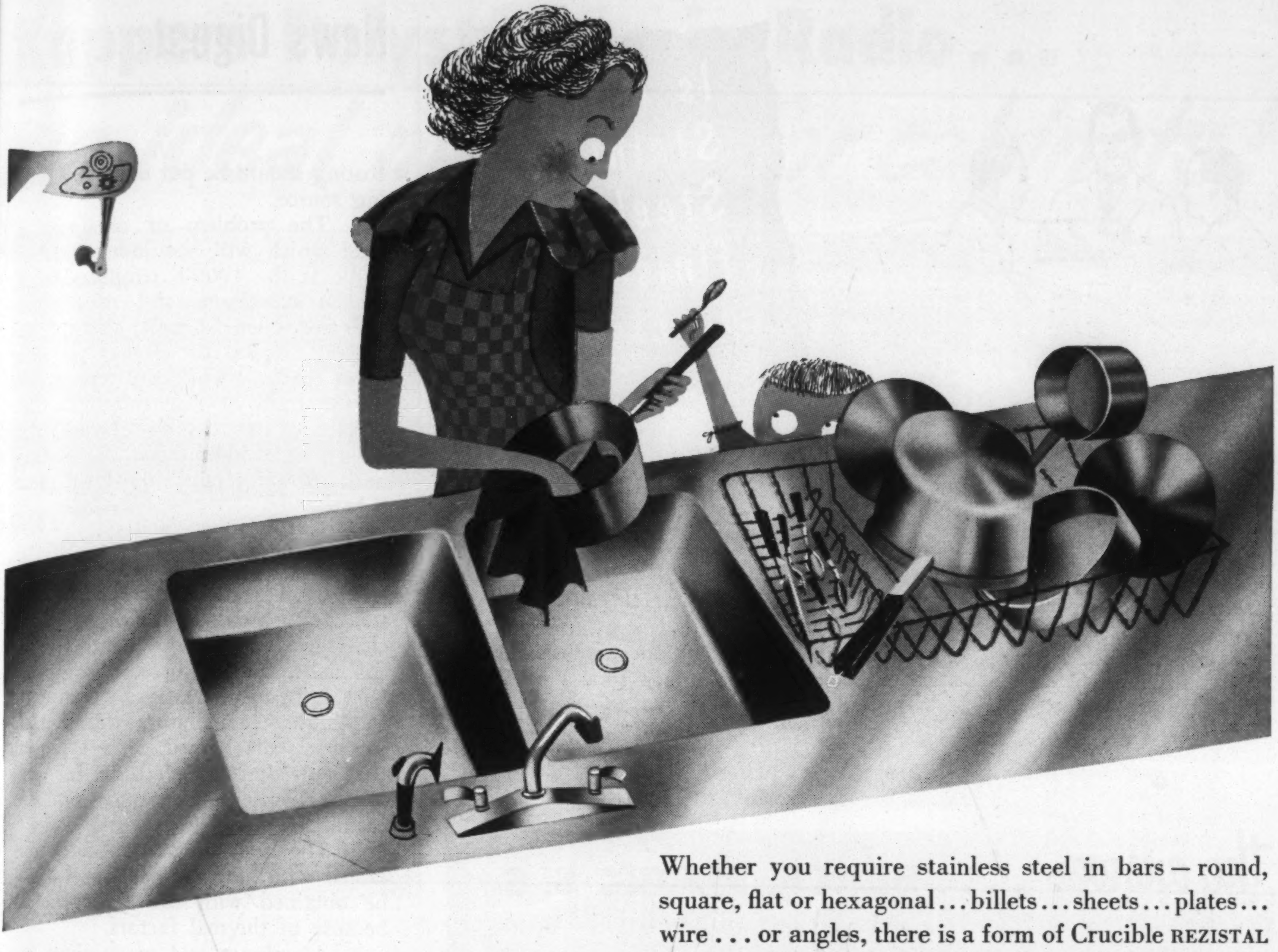
But, as M. R. Caldwell and C. Pack of Doehler-Jarvis Corp. pointed out recently, several other factors make the choice more difficult in the field of decorative automotive parts. In a paper given at the SAE National Passenger Car, Body and Materials Meeting held in March at Detroit, they discussed the influence of design, chemical activity, die life and cost, production rate and finishing on metal selection.

Their points can be summarized as follows:

Design Limitation

1. At present, most zinc die castings require no polishing before buffing; the light metals do. Therefore, a light metal part cannot have any fine ornamental engraving, since it would be destroyed by polishing. Designs with sharply recessed areas inaccessible to a polishing wheel or abrasive strap would also be impractical in aluminum or magnesium.

2. Because of their high chemical activity, all magnesium castings must be protected. If the part is to be painted, a chromate or phosphate



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Crucible's staff of metallurgists and stainless fabricating specialists are well experienced in solving application problems in the chemical, food processing, dairy, textile, laundry, hospital, pulp and paper and a host of other fields — including uses for Crucible REZISTAL in household articles like cutlery, cooking utensils and the proverbial *kitchen sink*.

If you have a specialized application where the unique qualities of stainless will improve your product or your processing operations, don't hesitate to call in a Crucible representative who can give you the benefit of our broad experience. And when you buy stainless, be sure you specify Crucible REZISTAL, the quality brand of heat and corrosion resistant steels.

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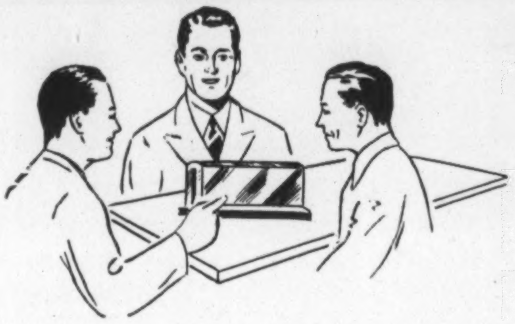

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News Digest

coating should be put on at the casting source.

3. The problem of obtaining a steel which will last indefinitely in a die at the 1200 F temperature of molten aluminum and magnesium has not been solved. A run of 25,000, 50,000 or so may produce "heat checks", which are reproduced in the form of fine ridges on the surface of the casting. Hence, the design of a light metal die casting must allow for polishing down these ridges.

Die Cost

4. Water cooling in the die is standard operation to keep production rates high. The possibility of cleavage cracks developing and making the entire die useless is greater with light metal castings because of the higher temperature differential. To meet this hazard, it is essential that two dies be available for any given aluminum or magnesium die casting.

5. The high production rates obtained with zinc die castings cannot be obtained with the light metals because of thermal factors.

6. Aluminum and magnesium require more die lubrication and, as a result, the castings have poorer surface finish than zinc die castings. Zinc die castings do not require the zinc immersion treatment used on the light metals.

News of Engineers

James N. Mason has been appointed to direct research and development for Boston Woven Hose & Rubber Co. Mr. Mason was formerly executive vice president of Interchemical Corp., Coated Products Div.

William P. Maginnis has been elected vice president and chief engineer of Federal Telephone and Radio Corp.

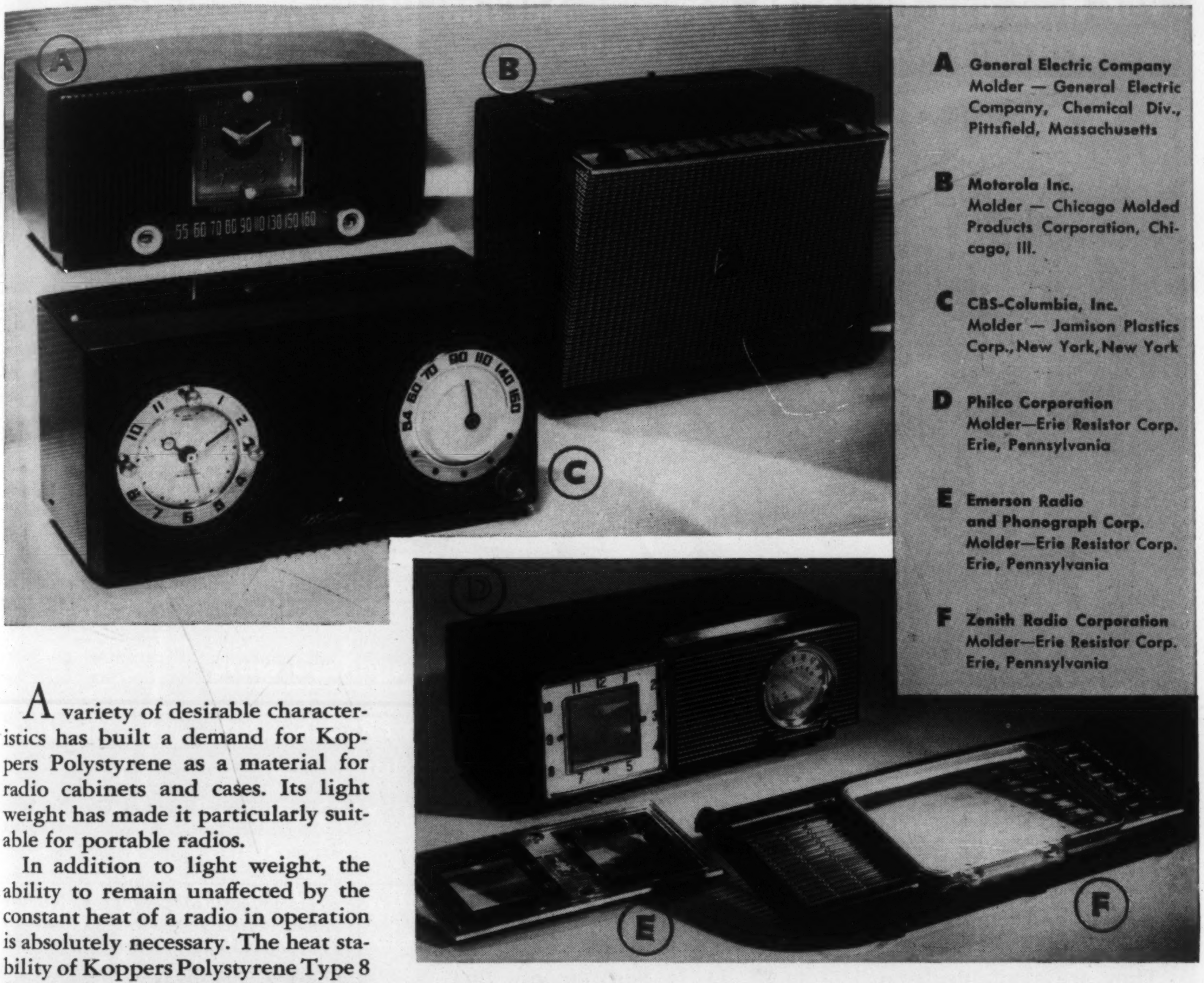
Tinnerman Products Inc. has announced the appointment of *Lawrence H. Flora* as director of engineering.

Dr. *Arthur A. Brown* has been named vice president of Bowser Technical Refrigeration.

William A. Reich has been appointed manager of advance development engineering at the Carboloy Dept., General Electric Co. Previously Mr. Reich was engineer in charge of the Metallurgy Sec-

Koppers Polystyrene in Radio...

an ideal material for cabinets!



A **General Electric Company**
Molder — General Electric Company, Chemical Div., Pittsfield, Massachusetts

B **Motorola Inc.**
Molder — Chicago Molded Products Corporation, Chicago, Ill.

C **CBS-Columbia, Inc.**
Molder — Jamison Plastics Corp., New York, New York

D **Philco Corporation**
Molder—Erie Resistor Corp. Erie, Pennsylvania

E **Emerson Radio and Phonograph Corp.**
Molder—Erie Resistor Corp. Erie, Pennsylvania

F **Zenith Radio Corporation**
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A variety of desirable characteristics has built a demand for Koppers Polystyrene as a material for radio cabinets and cases. Its light weight has made it particularly suitable for portable radios.

In addition to light weight, the ability to remain unaffected by the constant heat of a radio in operation is absolutely necessary. The heat stability of Koppers Polystyrene Type 8 is more than sufficient to satisfy this requirement. Strength, ease and speed of molding, dimensional stability for perfect mating of sections, and low cost are other characteristics of Koppers Polystyrene which make it a favorite material with manufacturers and molders.

Customers are attracted to radio cabinets of pleasing colors made possible by the use of Koppers Polystyrene. Manufacturers and molders have found that Koppers has eliminated the risk of visual variations in color. Koppers method of Color Matching and Control assures adherence to color specifications within exacting tolerances unsurpassed in the industry.

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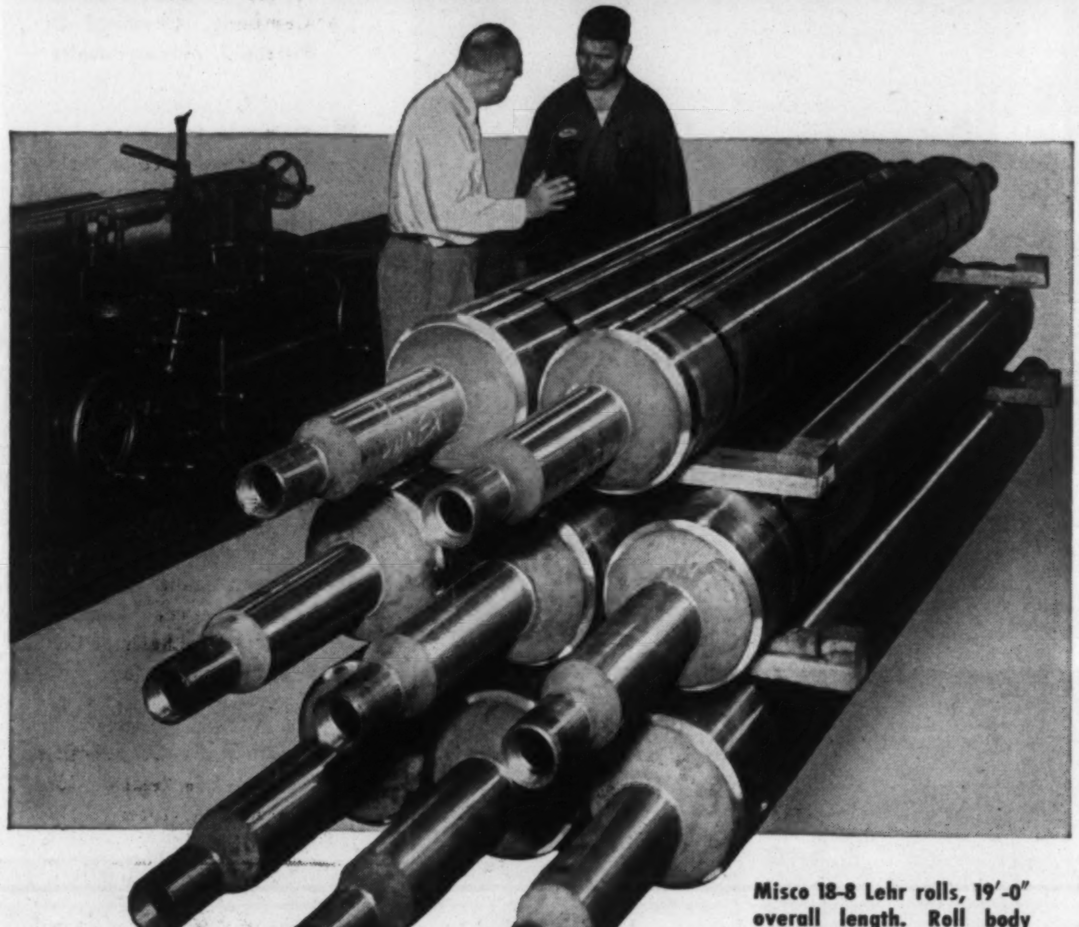

Misco 18-8 Lehr rolls, 19′-0″ overall length. Roll body 13″ diameter x 12′-11″ long. Finished weight 1700 pounds.

MISCO STAINLESS STEEL ROLLS are made by welding pairs of end trunnions to centrifugally cast tubes.

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News Digest

tion of the company's Turbine Div. Laboratory in Schenectady.

Three promotions in Buffalo Electro-Chemical's engineering department have been announced. *G. G. Crewson*, formerly chief engineer, has been appointed director of engineering; *J. N. Vermilya* succeeds Mr. Crewson as chief engineer; *Charles M. Standart* has been named assistant to Mr. Vermilya.

H. Thomas Hallowell, Jr., president of Standard Pressed Steel Co., has been named to receive the 1952 Achievement Award of the National Metal Trades Assn. for an outstanding contribution in the field of industrial relations.

Dr. *C. B. Post*, chief metallurgist, Research and Metallurgical Laboratories, Carpenter Steel Co., has been awarded the Bradley Stoughton plaque. The plaque is presented by the American Society of Metals, Lehigh Valley Section, to the Lehigh Valley metallurgist who has accomplished the most outstanding metallurgical work.

Jack H. Waggoner has been appointed technical assistant to the general manager of Pittsburgh Plate Glass Co.'s Fiber Glass Div.

S. S. Goodwin, manager of mines of the New Jersey Zinc Co., has been elected a vice president of the company.

Reorganization of personnel of Buckeye Brass and Mfg. Co. has been announced. *Don F. Shook* succeeds *Otto G. Gundel* as president; *Leon Disinger* will continue as vice president and general plant manager; and *Alan S. Dale*, formerly vice president and director of Randall Graphite Bearings Co., has been appointed vice president and general sales manager.

Norton Co. has announced the following promotions: *John Jeppson*, formerly assistant secretary and works manager, was appointed vice president and remains works manager of the Abrasive Div.; *A. Donald Kelso*, president of Norton Behr-Manning Overseas Inc., becomes a vice president in charge of foreign operations and a director, and also retains his former post.

Olin Industries, Inc. has named five department managers of its new General Research Div.: Dr. *Herman Bruson*, Organic Chemical Research; *Melvin M. Johnson, Jr.*, Armament Research; *Hibben Ziesing*, Petrochemical Research; *Robert L. Womer*, New Products Research; and Dr. *Oscar J. Swenson*, Chemical Engineering Research.

James M. Dehn has joined the engineering staff of Peter A. Frasse and Co., Inc. to serve as a field consultant on the application, selection and fabrication of stainless steels.

Appointment of *A. E. Kimberly* as chief engineer, DeSoto Div., and *Robert Anderson* as chief engineer, Plymouth

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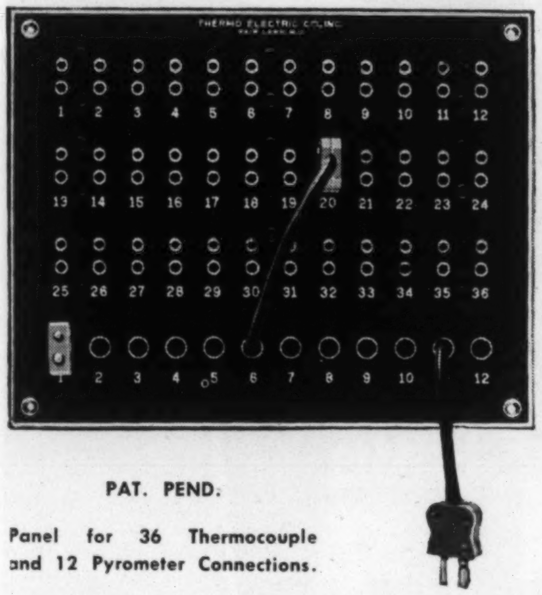

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Polarized Plugs and Jacks are made in all standard calibrations — Iron Constantan, Copper Constantan and Chromel Alumel.

Catalog Section 23G fully describes these Panels. Write for your copy today.

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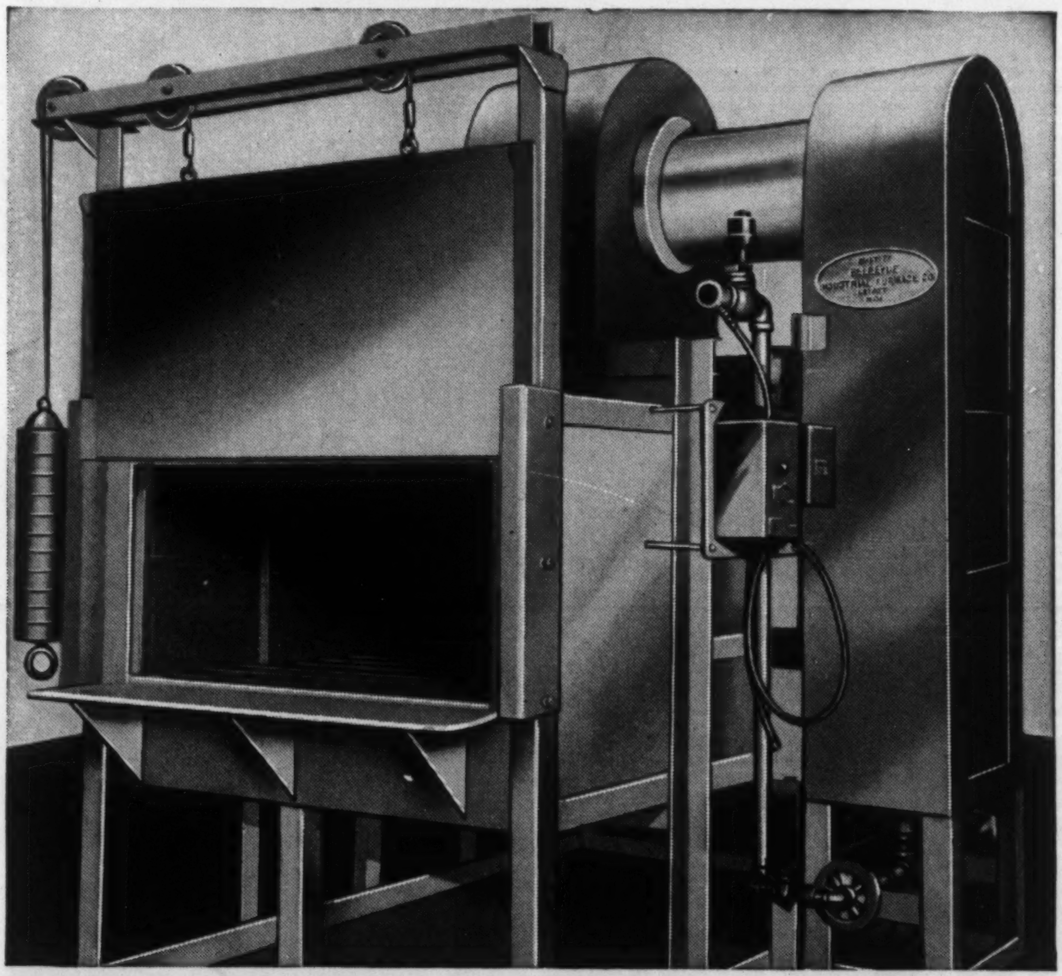

Batch type furnace for the heat treating of aluminum alloys—consists of atmosphere type burner mounted on the lower end of the combination chamber to reheat the recirculated hot air through the furnace. A High Heat insulated recirculating fan is standard equipment for recirculating the heated air. This method of heating holds temperature with little or no variation. Mounting the burner in the duct, eliminates the necessity of an extra heating unit. . . . Send us your heat treating problems . . . our engineers will make a proposal without obligation.

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News Digest

Div., has been announced by Chrysler Corp.

Bethlehem Steel Co. has announced the following promotions and appointments: *William P. Hill*, from assistant general manager of the Sparrows Point, Md., steel plant to assistant to vice president, Steel Div.; *John S. Marsh*, from research engineer to assistant chief of research; *C. Thompson Stott*, from chief metallurgist at Sparrows Point to assistant general manager of the plant; *W. D. Poole*, from assistant chief metallurgist at Sparrows Point to chief metallurgist of the plant; and *J. J. Link*, from assistant metallurgical supervisor, Tin Mills Div., to assistant chief metallurgist at the plant.

Robert C. Case, technical superintendent of the Gadsden, Ala., plant of The Goodyear Tire & Rubber Co., has returned to assume new duties as chief engineer of the Tire Design Div. of the company. *M. H. Laatsch*, chief chemist at Gadsden, moves into the post vacated by Mr. Case; and *J. L. Ryan*, assistant chief chemist, moves into Mr. Laatsch's former position. At the same time, *R. R. Adams* was named manager of technical service at Gadsden. Changes within the Goodyear Aircraft Corp.'s Engineering Div. are as follows: *E. A. Brittenham* has been named assistant chief engineer; *C. J. Pennig* has been appointed manager of the new Piloted Aircraft Engineering Div. In the newly-created division, *W. G. E. Mosebach* is manager of the Product Engineering Dept. and *J. W. Laister* is assistant manager; *D. W. Brown* is manager of airframe installations design, and *R. E. Anthony* is manager of structural design; *P. E. Ziegler* is manager of project engineering and preliminary design; *H. R. Liebert* continues as manager of LTA special projects; *Edgar Everhart, Jr.* continues as manager of fabric coordination; *R. L. Ravenscraft* is manager of engineering technical service, and *J. F. Snider* is assistant manager of the department.

News of Companies

North American Philips Co., Inc. has added a *Department of Non-Destructive Testing* to the X-ray Div., 750 S. Fulton Ave., Mt. Vernon, N. Y.

Pioneer Electronic Corp. is constructing a new plant for manufacturing television picture tubes, said to be the first of its kind in the West. Located in West Los Angeles, the new plant will have 30,000 sq ft of enclosed space and 20,000 sq ft of paved ground for parking, loading and potential expansion.

Bigelow-Sanford Carpet Co. is entering the field of fabricating glass fiber rein-

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HEAT AND CORROSION RESISTANT

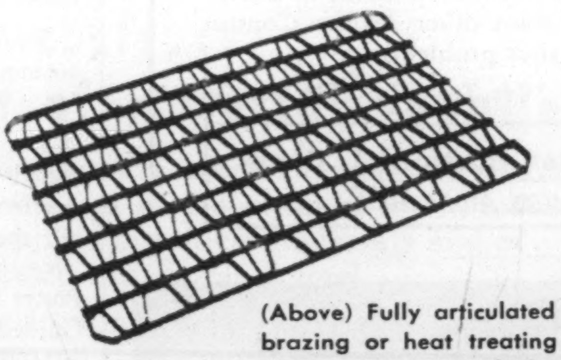
FABRICATED ALLOYS

(Above) Rugged assembly for carburizing shafts in pusher furnace. Adjustable posts position fabricated alloy screens; mesh to suit work. Light weight, high pay load, long life.

WHY FABRICATED?

All Rolock heat treating equipment is fabricated... not cast. Every carrier is job-engineered for the specific use and made from the correct metals and alloys for maximum resistance to all conditions of exposure, shock and abrasion. Especially successful are Rolock applications of nickel alloys . . . replacing heavy castings with durable, lighter weight fabrications. The examples shown below, while custom-built, can be adapted to your needs. We welcome your requests to solve your heat treating equipment problems.

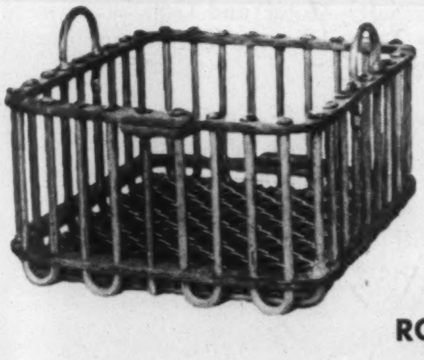
(Above) Inconel basket assembly for nitriding. Only required baskets need be used for less than capacity operation . . . reducing furnace load.



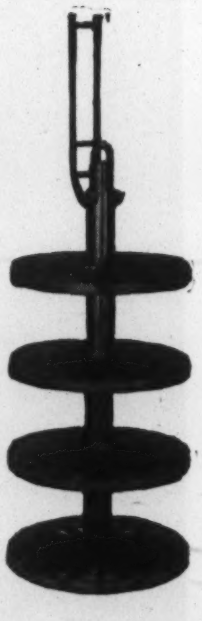
(Above) Fully articulated "Serpentine" brazing or heat treating tray, retains shape. Heavy or light, any width, length, depth. Many uses at lowest hourly cost.

(Below) Inconel muffle for hardening roller bearing parts in gas furnace, with propane and cracked ammonia atmosphere. Flange faces machined for gas-tight service at 1600° F.

(Right) Stainless drop-bottom pit furnace basket for quality, uniform heat treat. Saves seconds between heat and quench.



(Left) Alloy carburizing basket. Loose joints expand under heat. Rugged, flexible construction resists abuse.



(Right) Sectional lift post carburizing fixture. Most versatile for handling variety of parts. Each loaded grid quenched separately, if desired.

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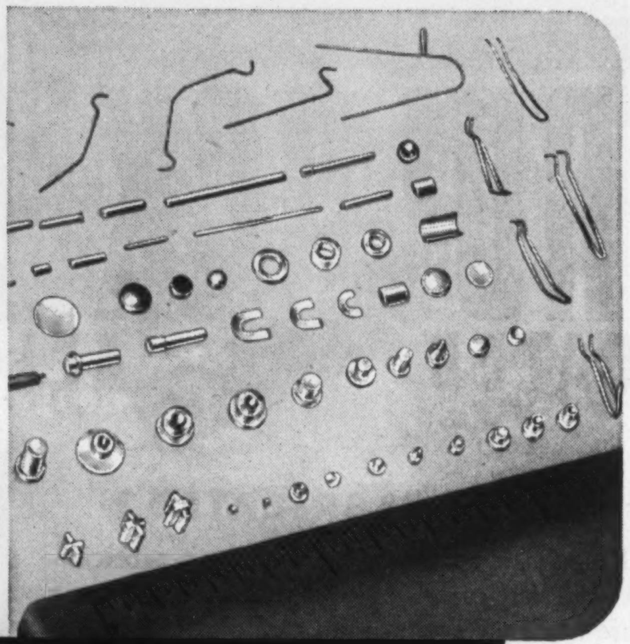

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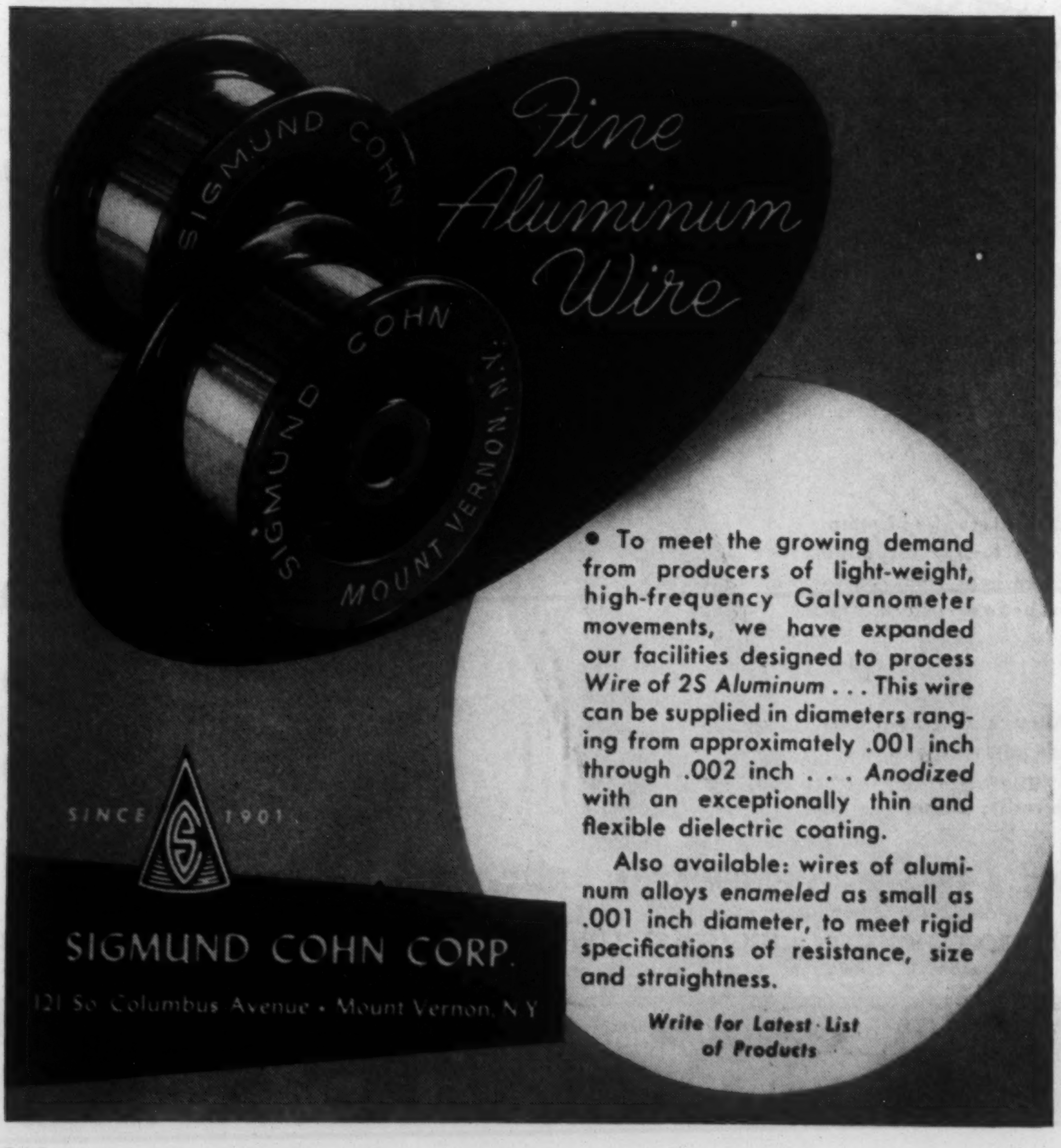

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Also available: wires of aluminum alloys *enameled* as small as .001 inch diameter, to meet rigid specifications of resistance, size and straightness.

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SINCE 1901

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News Digest

forcing materials for use in reinforced plastics. Initial facilities have been set up at Thompsonville, Conn., in conjunction with the company's developmental laboratories and pilot plant. New products in limited production include a uniform glass fiber mat in weights from 2 to 10 oz. per sq. ft. and glass fiber cloth in widths up to 150 in.

The Vacuum Equipment Dept., Distillation Products Industries, will become *Consolidated Vacuum Corp.*, a subsidiary of *Consolidated Engineering Corp.*

In order to provide industry with optimum engineering, production and research services in the fields of filtration and porous media, three manufacturing and engineering organizations have affiliated as *The Pall Filtration Companies*, under the leadership of Dr. David B. Pall. The companies are: *Micro Metallic Corp., Aircraft Porous Media, Inc.*, and *The Porous Plastic Filter Co.* The mailing address of the new organization is Glen Cove, N. Y.

Solar Steel Corp. has purchased the business of the *United Steel Products, Inc.*, Worcester, Mass.

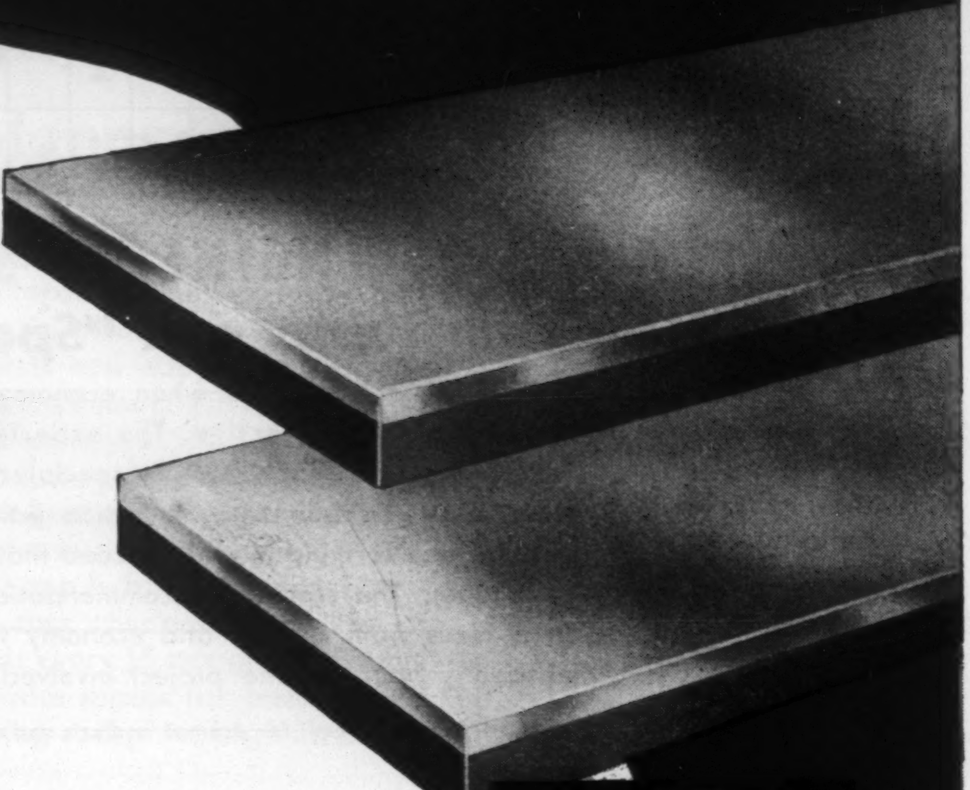
Two new operations have been established within *General Electric's Aeronautic & Ordnance Systems Div.* They are the *Guided Missiles Dept.* and the *Aircraft Products Dept.* Dr. Richard W. Porter was named general manager of the Guided Missiles Dept., and Fred B. Law general manager of the Aircraft Products Dept. The *Small and Medium Motor Dept.* of G-E has been discontinued and its operation has been decentralized into three new product organizations. A divisional marketing department was also established to facilitate a unified approach to all division marketing policies. The four new departments and their managers are: *Marketing Dept.*, Walker H. Henry; *Medium Induction Motor Dept.*, Olaf F. Vea; *Direct Current Motor and Generator Planning Study, Oscar L. Dunn; Synchronous and Specialty Motor and Generator Dept.*, Fred B. Hornby. Headquarters for the first three organizations will be at Schenectady, N. Y., and the Synchronous and Specialty Motor and Generator Dept. will be located at the G-E Lynn, Mass., River Works.

Adamas Carbide Corp. has opened a new $250,000 stock of standard tungsten carbide in Dearborn, Mich. *Quint-Alloy Corp.*, Adamas representatives in Michigan, will handle the stock in their new headquarters at 24141 Ann Arbor Trail, Dearborn.

Steiner Plastics Manufacturing Co., Inc. has purchased a 10,000 sq. ft. one-story building at 1 Bay St., Oyster Bay, L. I., N. Y., to be used exclusively for the fabrication of reinforced plastic parts.

Formation of *The Perry Co.*, manufacturers of the Perry cooling system filter, as a wholly-owned subsidiary of

the switch is to STAINLESS-CLAD PLATES



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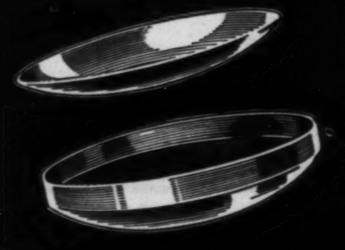
More and more, economy-minded buyers are switching to Stainless-Clad Steel Plates as an effective means of extending supplies of critical materials and of beating the high cost of stainless steel.

They find that in numerous types of fabrication these plates give them all the advantages of stainless steel, including high resistance to corrosion—yet with considerable savings in material costs.

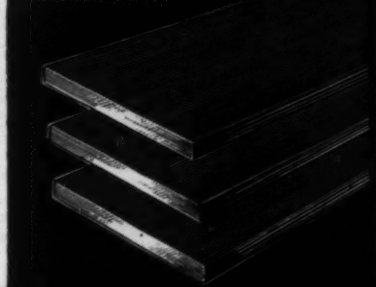
Stainless-Clad Plates made by Claymont are a composite of stainless steel permanently bonded to carbon or alloy steel plate. They're easy to fabricate; will not buckle, crack or peel under the severest forming operations. Stainless cladding may be of any specified percentage of total plate from 10% to 50%.

Other Claymont products include Flanged and Dished Heads, Alloy and Carbon Steel Plates, Large Diameter Welded Steel Pipe.

To order, write or call Claymont Steel Products Department, Wickwire Spencer Steel Division, Claymont, Delaware.



Flanged and Dished Heads



Carbon and Alloy Steel Plates

Large diameter steel pipe

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THE CALIFORNIA WIRE CLOTH CORPORATION—Oakland, California
WICKWIRE SPENCER STEEL DIVISION—Atlanta • Boston • Buffalo • Chicago • Detroit • New York • Philadelphia
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PRODUCTS OF WICKWIRE SPENCER STEEL DIVISION
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COSTS dictate methods when economy of production is your objective. The experience and knowledge of PHOENIXSPUN specialists quickly determine the quantity production point where costs of one forming method exceed that of other techniques. The resulting recommendation brings to a focus both quality and economy factors in efficiently handling the project involved.

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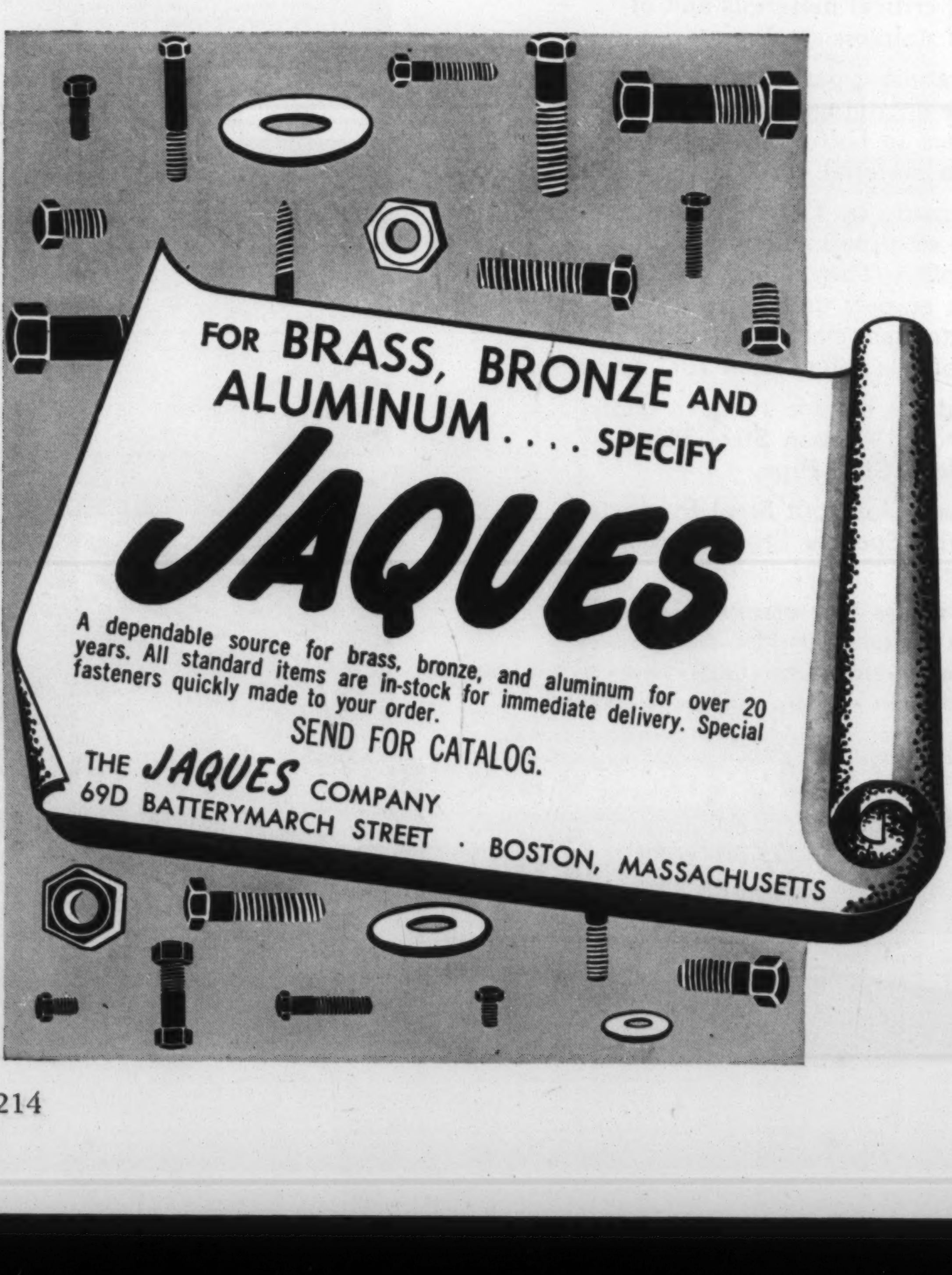

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the R. M. Hollingshead Corp. has been announced.

Charles H. Judd, known nationally for his contributions to the stamping industry since 1935, has formed *Judd Industries, Inc.*, located at 3148 W. 32nd St., Cleveland 9.

News of Societies

Carl L. Ipsen retired from General Electric Co. to become executive vice president of the *Industrial Furnace Manufacturer's Assn.* in Washington, D. C.

Roger F. Waindle was elected president of the 25,000-member 105-chapter *American Society of Tool Engineers* at the 21st annual meeting of the Society. Mr. Waindle, vice president, Cannon-Muskegon Corp., succeeds L. B. Bellamy of Detroit. Elected with Mr. Waindle were: first vice president, Joseph P. Crosby, vice president, The LaPointe Machine Tool Co.; second vice president, Dr. Harry B. Osborn, Jr., Technical Director, Tocco Div., The Ohio Crankshaft Co.; third vice president, Howard C. McMillen, plant manager, Philco Corp.

Dr. Donald B. Prentice, national director of the *Scientific Research Society of America,* presented a charter to the M. W. Kellogg branch of the Society at a recent ceremony held at the New York University Club.

The New York Metropolitan area and the Southern Connecticut and Northern New Jersey industrial areas celebrated Tool Engineering Day on Apr. 14. Celebration included plant tours in a number of the leading industrial plants and was sponsored by the six chapters of the *American Society of Tool Engineers* in the area. A banquet session of the events was held at the Hotel New Yorker.

New officers of the *Society of Plastics Engineers* were elected for 1953. They are: Walter C. Oelman, vice president and general manager of Standard Molding Corp., president; Stanley Bindman, vice president of Jamison Plastics, vice president; John W. LaBelle, New England district manager, Koppers Co., secretary; Richard Bruce, regional representative, Bakelite Corp., treasurer.

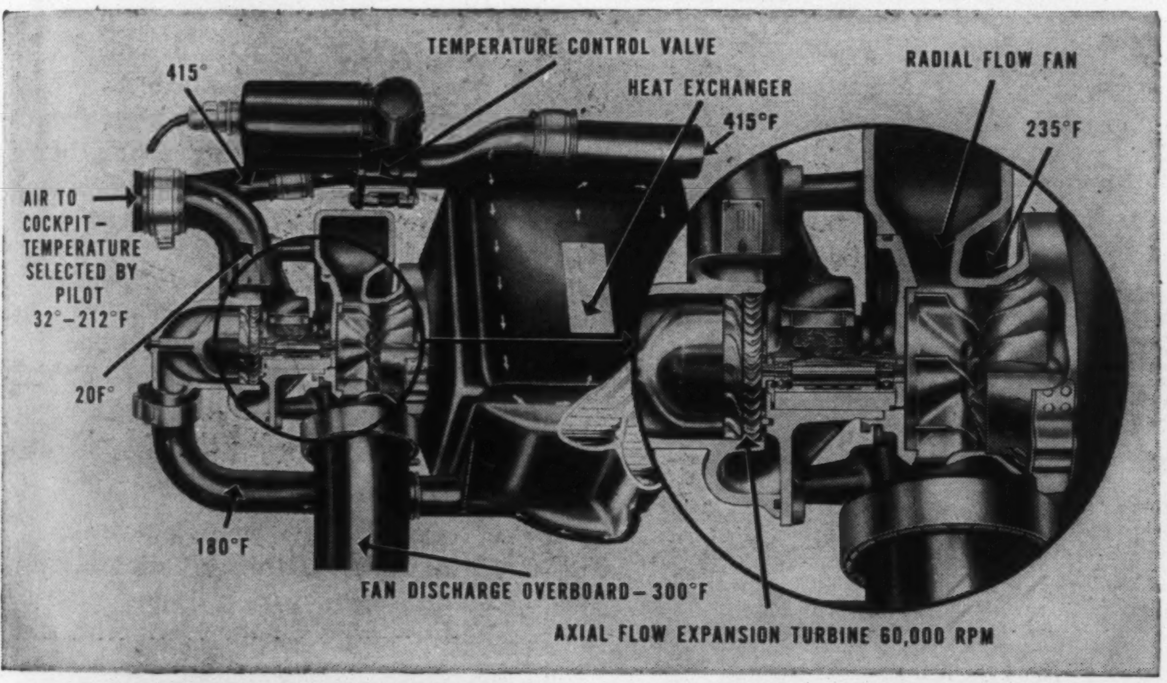
At the annual meeting of the *Aluminum Assn.*, D. A. Rhoades, Kaiser Aluminum & Chemical Corp., was elected president for the ensuing year. Elected to serve as vice president were: S. D. Den Uyl, Bohn Aluminum & Brass Corp.; Raymond Deutsch, Monarch Aluminum Mfg. Co.; and R. P. Stranahan, Stranahan Foil Co.

Metallurgists:

Can you help solve this problem for tomorrow's planes?

Problem: Cockpit temperature of present day jet aircraft flying 600 m.p.h. at sea level would reach 190°F. (caused by a combination of compression, friction of plane's skin with air, solar radiation, electrical equipment and pilot's body heat). How to reduce this temperature to a safe, comfortable level with equipment of minimum size and weight, yet capable of withstanding extreme conditions of heat and cold, erosion, corrosion, and numerous mechanical stresses which occur in high-speed flight?

Our Answer: A compact, 20 lb. unit, developed by Hamilton Standard engineers, in which some 25 different basic metals and alloys are used. It bleeds air from the engine compressor at approximately 415°F. . . . extracts 150,000 b.t.u.'s per hour by feeding it through a heat exchanger and 60,000 r.p.m. expansion turbine wheel . . . delivers 120 m.p.h. blast at desired temperature that changes 60 cu. ft. of cockpit air every 15 seconds. The unit also provides means for heating and pressurizing cockpit at high altitudes.


TEMPERATURE CONTROL VALVE
415°
HEAT EXCHANGER
415°F
RADIAL FLOW FAN
235°F
AIR TO COCKPIT-TEMPERATURE SELECTED BY PILOT 32°-212°F
20F°
180°F
FAN DISCHARGE OVERBOARD-300°F
AXIAL FLOW EXPANSION TURBINE 60,000 RPM

What's Your Answer? Our cockpit cooling unit is operating with excellent efficiency in many of today's jet aircraft. But in order to solve similar problems in the much faster flying planes of tomorrow, we will need entirely new systems that call for even further development in the field of physical metallurgy.

At Hamilton Standard there are many other challenging projects for metallurgists, too. This unit is only part of a growing line of jet aircraft equipment which already includes turbine engine starters, fuel controls, hydraulic pumps, and auxiliary drives and controls for guided missiles. There are also many exciting new developments in world-famous Hamilton Standard propellers.

Creative Engineering Pays Off at Hamilton Standard

We're always looking for ideas — and at Hamilton Standard ideas pay off. A majority of our company executives are engineers. We have a technical staff of more than 250 now — young, capable, progressive leaders — and we need more to meet the largest research and development program in our 33 year history. If you are one of the metallurgists we're looking for, there's a bright future for you at Hamilton Standard.

There's a Future at Hamilton Standard

for Metallurgists

with 3 to 5 years' experience in the field of physical metallurgy. There are openings in both development and quality control, working with a

Wide Variety of Metals and Alloys

including carbon, low alloy, high speed and stainless steels, copper, aluminum, magnesium, silver and titanium alloys—and many others too numerous to mention.

These Positions Offer

- **Excellent pay and a fine chance for advancement based on ability.**
- **A unique opportunity to use your education to the fullest extent on a wide diversity of materials.**
- **Association with exceptionally high calibre engineering staff — with freedom of decision and responsibility.**
- **Good housing available in an ideal location with every cultural and recreational advantage — midway between Hartford, Conn., and Springfield, Mass.**
- **New plant with modern air conditioned offices in a beautiful country setting.**
- **Secure future with a progressive company whose technical staff has grown steadily for 33 years.**

Send resume of your experience to

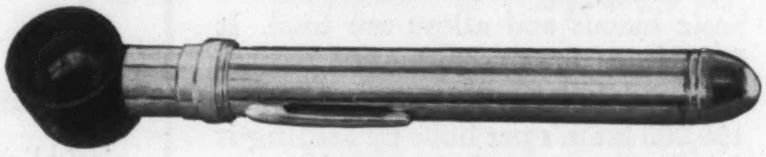
**Engineering Representative
Personnel Department, Section C**

Hamilton Standard

**Division of United Aircraft Corp.
Windsor Locks, Conn.**

How to speed production with MAGNIFIERS

New! Illuminated 10x Pocket Magnifier



WRITE for new handbook and catalog, "Industrial Magnifiers—How to Choose and Use Them." Bausch & Lomb Optical Company, 50317 Bausch St., Rochester 2, N. Y.

INDUSTRIAL
Magnifiers
HOW TO CHOOSE AND USE THEM

Cut waste, get faster, surer inspection by fitting the magnifier to the job. This new Bausch & Lomb Illuminated Coddington floods entire viewing field with bright light *through* the lens, permitting quick, accurate on-the-spot inspection, without need for outside lighting. Image quality is excellent! Carry this new magnifier with you always—anywhere $7.50

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New concept in photography

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Gets the action every time because it's Motorized!

Now equipped to take 35mm standard cartridges.

Set the Robot-Star just once, and you're all set for as many as 24 (or 48) exposures, made singly or in rapid-fire sequence, as fast as 8 per second! Robot-Star automatically moves film and resets shutter after each exposure. Surpasses human efficiency because of its built-in clock-work motor. Remote control release and other accessories bring new camera applications never before thought possible in science and industry as well as for personal use.

Takes any standard film—color, too. Gets 50% more pictures, with 55 exposures instead of 36 per loading. Choice of Schneider lenses, wide angle to telephoto. For new camera thrills—get Robot-Star—from $217.50.

Write for authoritative treatise T—"New Techniques in Photography for Industry and Science"—Sent without charge.

INTERCONTINENTAL MARKETING CORP.
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Briefs

"ALUMINUM" BEARINGS Bearings consisting of a cadmium-silicon-aluminum alloy on steel backing have outlasted three or four crankshafts and blocks in tests conducted by an auto manufacturer.

BORON STEELS Nitrogen content appears to have an important bearing on why boron additions sometimes fail to produce the expected increase in hardenability of steels. With high nitrogen content, complex compositions are needed to introduce the boron effectively into the steels and such compositions tend to impair impact and ductility properties.

SURFACE ROUGHNESS An instrument known as the Surfagage, which can detect a scratch as small as a millionth of an inch, has been developed by the GM Research Laboratories Div. for measuring surface roughness of metals.

RIGIDIZED METAL Rigidized sheet metal has replaced an abrasive paint on drums which make use of friction to drive yarn-twisting spools in the textile process known as "roving". The metal was adopted to save on repainting costs.

TUBELESS TIRE A tubeless tire for aircraft developed by Firestone Tire & Rubber Co. and using nylon fabric is said to be 20% lighter than a postwar rayon tire with tube. Weight saved per airplane ranges from 7 to 125 lb.

SHELL MOLDING A molding machine which will sell under $2500 and is expected to bring the shell molding process within reach of the small foundry has resulted from studies in Stanford University's industry laboratory.

RUBBER IN WAR First draft of a plan for maintaining production of critical rubber products following a hypothetical atomic attack has been prepared by the National Production Authority and is under study by an industry group.

NICKEL AND COBALT About 90% of available supplies of nickel and cobalt are currently being consumed by defense industries.

STAINLESS MOVES UP Output of stainless steel last year was 0.97% of total raw steel output, compared to 0.89% in 1951. The percentage of stainless produced to total steel has moved up almost every year since the early '30's.

PYLE NATIONAL INCREASES PRODUCTION 47%!

Soldering Of Spring Assemblies Speeded By *LINDBERG* Induction Heating Unit

An hourly production increase of 47% . . and a per-operator production increase of 330% through the use of a Lindberg Induction Heating Unit! These are the money saving facts and figures reported by Pyle National Co., Chicago manufacturer of electrical components.

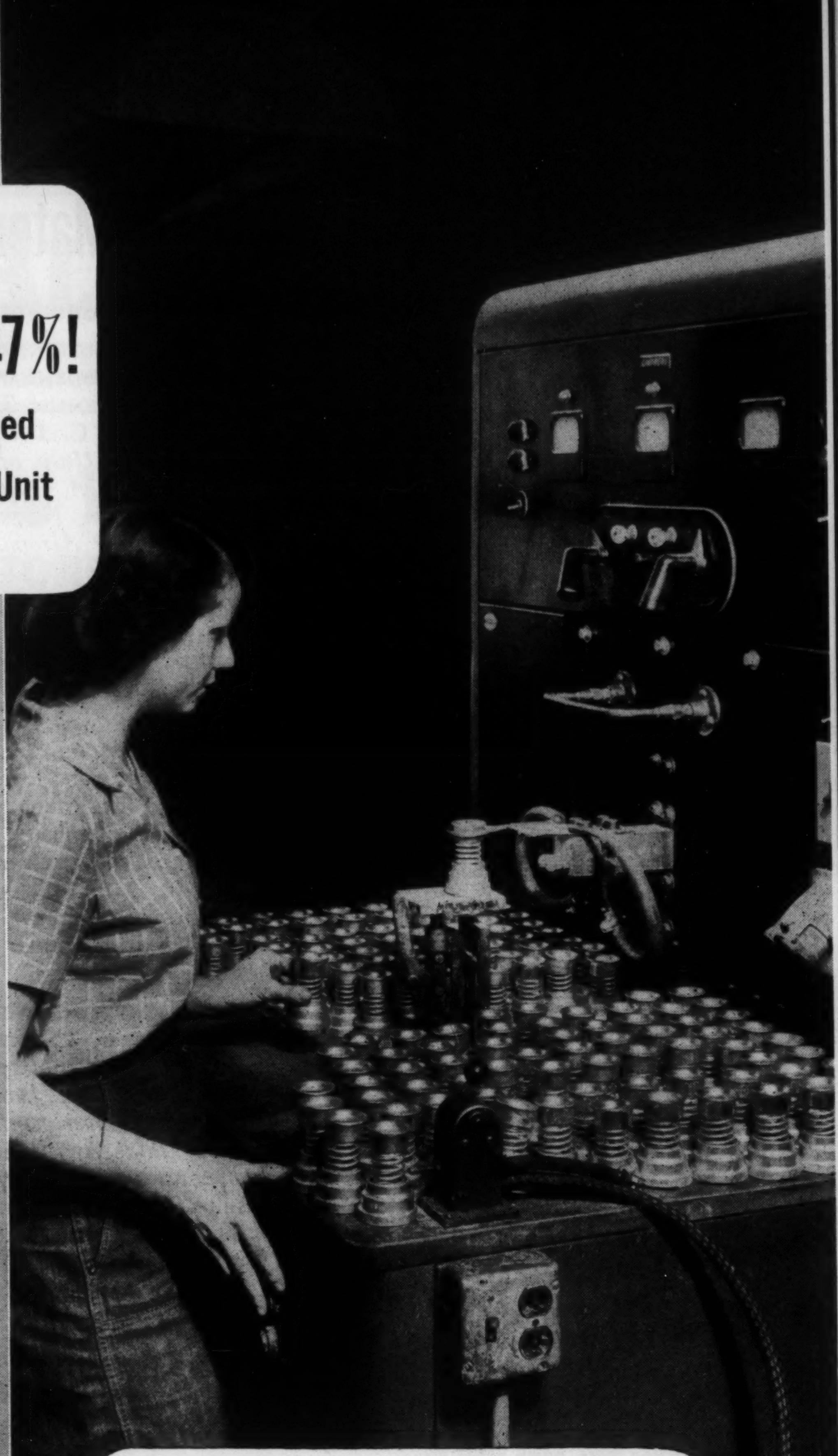
The company uses a 10 KW Lindberg unit for the production soldering of flanges to coil springs in the manufacture of torsion spring assemblies. The time cycle is 11 seconds for each assembly.

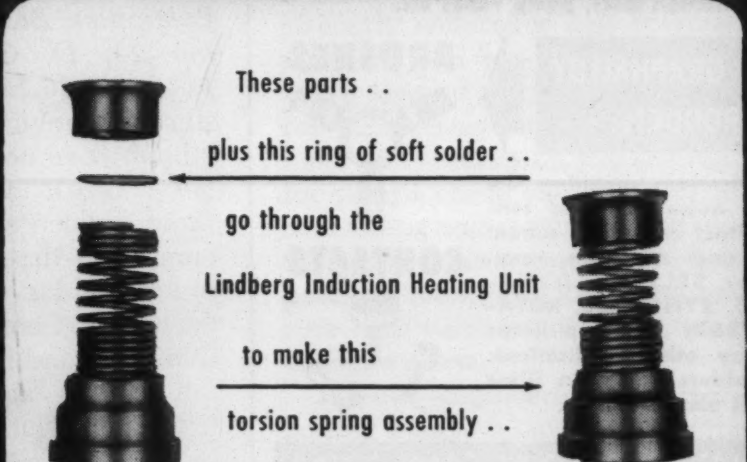
Production has been increased to 125 assemblies an hour . . with one girl operating the equipment. This is an hourly increase of 40 assemblies over the former method where soldering was done by a team of three men using gas torches. And the hourly per-operator production is up from 28 to 125!

With the induction heating unit, there are no open flames from gas torches. No extra exhaust fans are required . . there is little danger of burns to operators . . fire hazards are virtually eliminated!

And there is a substantial economy of floor space! Formerly the three torch operators required more than 60 square feet of floor space . . but the Lindberg Induction Heating Unit requires less than 30 square feet.

If your requirements call for production soldering, brazing, hardening, annealing, stress relieving, hot forming, forging or shrink fitting, investigate Lindberg Induction Heating Units. Ask for Bulletin 1440.





These parts . .

plus this ring of soft solder . .

go through the

Lindberg Induction Heating Unit

to make this

torsion spring assembly . .

LINDBERG

HIGH FREQUENCY DIVISION

LINDBERG ENGINEERING COMPANY,
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GRAPHALLOY
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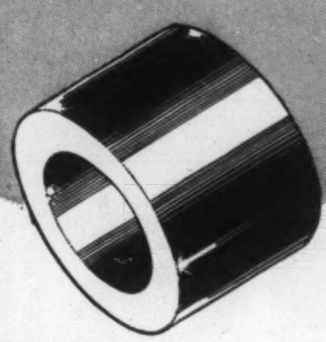
OIL-FREE
SELF-LUBRICATING
BUSHINGS



"WORK WHERE OTHERS WON'T"

Widely Used Where Ordinary
Oil Lubrication Is
Impractical or Impossible.

EXCELLENT DURABILITY • CONSTANT CO-EFFICIENT OF FRICTION • APPLICABLE OVER A WIDE TEMPERATURE RANGE — EVEN WHERE OIL SOLIDIFIES OR CARBONIZES • OPERATE DRY, OR AT HIGH SPEEDS SUBMERGED IN WATER, GASOLINE AND OTHER LIQUIDS • EXCELLENT FOR CURRENT-CARRYING BEARINGS

GRAPHALLOY materials are also in wide use for oil-free, self-lubricating piston rings, seal rings, thrust washers, friction discs, pump vanes etc.

OTHER GRAPHALLOY PRODUCTS

BRUSHES

For applications requiring low electrical noise, low and constant contact drop, high current density and minimum wear. Used for SELSYNS, DYNAMOTORS, SYNCHROS, ROTATING STRAIN GAGE pick-ups and many other applications. Brush Holders and Coin Silver Slip Rings also available.

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Technical Reports on Materials

Ferrous Alloys

SURVEY OF PORTIONS OF THE IRON-NICKEL-MOLYBDENUM AND COBALT-IRON-MOLYBDENUM TERNARY SYSTEMS AT 1200 C. *Dilip K. Das and Paul A. Beck, Univ. of Notre Dame (1953). NACA TN 2896, 56 pp. Available from National Advisory Committee for Aeronautics, 1724 F St., Washington 25, D. C.*

SAG RESISTANT PROPERTIES OF METALS AND ALLOYS. *Univ. of Illinois. Report PB 107985. Available from Library of Congress, Publication Board Project, Washington 25, D. C. Microfilm $2.00, photostat $3.75.* Ingot iron; low carbon steel; Ti-Namel; four titanium-boron bearing metals, designated 1446, 1447, 1448 and 1449; stainless steel types 302, 310, 316, 321, 347 and 430; and Inconel were evaluated. Some metals were ceramic-coated and tested.

FERROMAGNETISM AND THE CURIE POINT. *B. M. Aldrich, Oklahoma A&M College. Publication No. 83, 42 pp. Available from Oklahoma Engineering Experiment Station, Stillwater, Okla.* Any change in critical temperature which may occur as a result of an impressed magnetic field is not sufficient to make possible its use in the heat treatment of the compositions of steel studied.

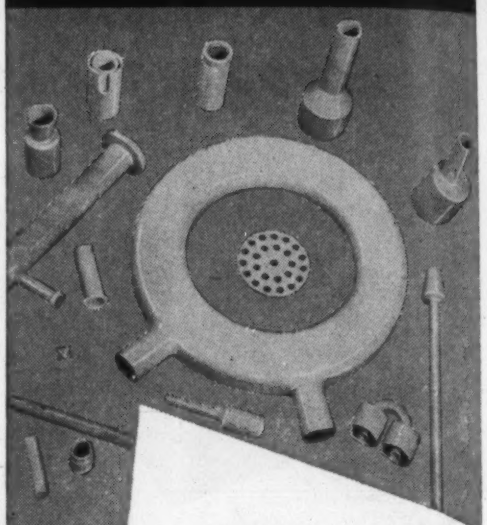
IMPROVED MAGNETIC MATERIALS. *Third Quarterly Report for the Period Apr. 15, 1951 to July 15, 1951. Lehigh Univ. Report PB 107815. Available from Library of Congress, Publication Board Project, Washington 25, D. C. Microfilm $2.50, photostat $6.25.* Small amounts of silicon, titanium, beryllium and aluminum have been added to 50 iron-50% cobalt alloy. Thermal data show influence of silicon and titanium on the alpha to gamma and order-disorder transformation temperatures. Complete electrical resistivity data and initial x-ray data show influence of aging temperature and time upon solution treated Vicalloy I.

Light Metals

THE YOUNG'S MODULUS, POISSON'S RATIO AND RIGIDITY MODULUS OF SOME ALUMINUM ALLOYS. PART II. *N. Dudzinski, Royal Aircraft Establishment, Great Britain (1952). Report N-21258, 28 pp. Available*

(Continued on page 222)

McDANEL
HIGH TEMPERATURE
PORCELAIN
SPECIALTIES...



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Industrial
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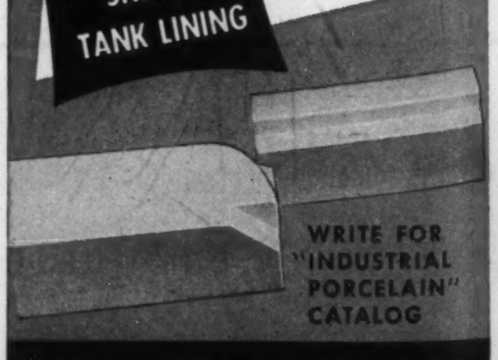
Precision-made McDanel flasks, crucibles, combustion tubes, zirco tubes and other standard and special laboratory items are outstanding in quality and performance.

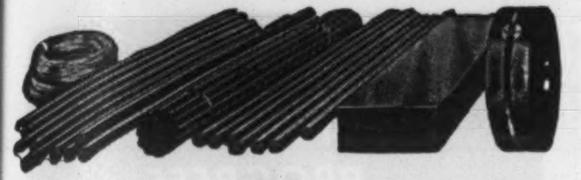
McDanel High Temperature Specialties undergo the most exacting inspections and checking at every stage of design and manufacture. They are trust-worthy. They have proved themselves by their record of more than 34 years' servcie in the nation's leading laboratories.

MILL LINING
SPECIAL
SHAPES
TANK LINING



WRITE FOR
"INDUSTRIAL
PORCELAIN"
CATALOG

McDANEL
REFRACTORY PORCELAIN CO.
BEAVER FALLS, PENNA.



BRIDGEPORT BRASS COMPANY

COPPER ALLOY BULLETIN

BRASS Bridgeport CO. MILLS IN BRIDGEPORT, CONN. AND INDIANAPOLIS, IND.—IN CANADA: NORANDA COPPER AND BRASS LIMITED, MONTREAL

Sentinel Shower Mixing Valve Improved by Using Duronze III

Teamwork between the product engineer and metallurgist is most essential for products expected to function properly for many years.

Many a properly designed engineering product fails from wear or corrosion when unsatisfactory metals or alloys are used in its construction. Consequently, it pays to consult the laboratory before writing metal specifications.

A Better Mixing Valve

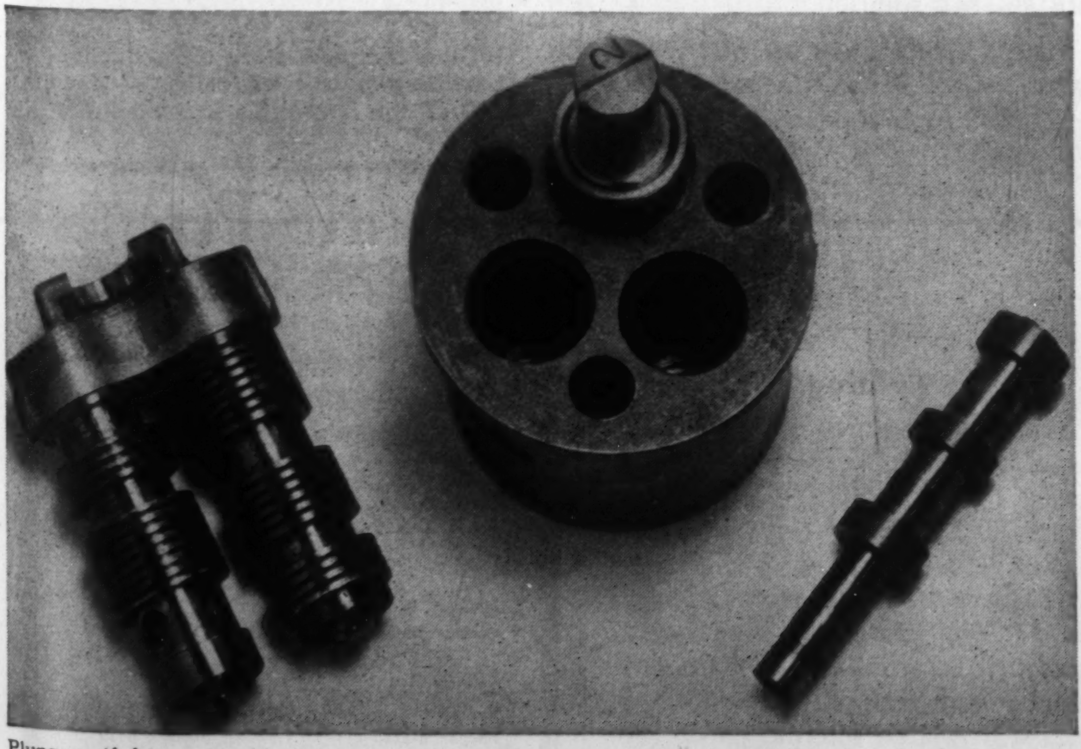
The balanced pressure mixing valve illustrated below is designed to hold the desired discharge temperature of the water by controlling the initial water pressure. It is accomplished not by thermostats, rockers, or springs, but by means of a floating piston or "Sentinel" (shown in the lower right-hand corner of the illustration below). This prevents sudden surges of steam, hot or cold water resulting from "water stealing" down the line. Even if the hot or cold water supply fails entirely, the "Sentinel" will immediately shut off the shower to a mere drip and then automatically restore the flow of water when the pressure returns.

This type of construction calls for extreme precision. Both the plungers and the floating "Sentinel" or piston must work freely in the valve block with very close tolerances. They must not contract, expand or change in size with wide temperature ranges of hot or cold. The metal must be hard and wear resistant. Yet it must have good machinability.

Duronze III, silicon aluminum bronze, containing approximately 91% copper, 7% aluminum, and 2% silicon meets all of these special requirements. In the annealed condition it has a tensile strength in the neighborhood of 90,000 pounds per square inch and a Rockwell hardness of B85. It has a machinability rating of 60% as compared to free cutting brass rod which carries a 100% rating.

Duronze III is supplied in rod form only—for making screw machine parts or for producing hot forgings.

When in contact with another metal or alloy such as brass, it has a low coefficient of friction and withstands wear from rubbing. It also has excellent resistance to corrosion from various types of waters, both hot and cold.



Plungers (left), valve block (center) where plungers are seated, and Floating Sentinel (right). Courtesy Speakman Company, Wilmington, Delaware.

COLD
SPEAKMAN
SENTINEL
HOT

Sentinel shower with any stream head. Courtesy Speakman Company, Wilmington, Delaware.

There are many places where Duronze III parts can impart greater strength, endurance and corrosion resistance to a product. Examples are valve stems for water valves; sleeves for compression fittings to reduce effects of vibration on the tubing; parts for pumps, check valves; water meters, controlling and regulating instruments; wire and cable connectors; oil burner nozzles; bolts, nuts, pole line and marine hardware; small gears, pinions—to name a few.

If your engineering department is getting ready to launch a new item, or is trying to improve an old one, or if your product is failing from excessive corrosion or wear, contact the nearest Bridgeport sales office for help from our metallurgical laboratory. Write for the "Duronze Manual," which contains engineering data on silicon bronze and silicon aluminum bronze. (9769)

650° F.
STEADY OR WITH RAPID FLUCTUATIONS
MYCALEX INSULATION CAN TAKE BOTH OF THOSE TEMPERATURE CONDITIONS

It holds inserts tightly, and moves with the metals around it, because it has very nearly the same coefficient of thermal expansion as the most important metals of which inserts and casings are made.

DESIGNER! UNCHAIN YOUR IMAGINATION!

The destructive effects of high operating temperatures, high ambient temperatures, thermal expansion as between metals and insulations, have caused you to make too many items too much bigger and heavier than they need to be.

MYCALEX glass-bonded mica also is dimensionally stable, corona resistant, does not carbonize under arc, has no moisture absorption.

Chatter-Less Brush Holder
Spur Gear
Plate Assembly for PA Timer
Threaded Coil Form
Coaxial Bushing

THERE ARE PLENTY OF OTHER USEFUL FEATURES . . . WRITE for the whole story

SINCE 1919
MYCALEX
THE INSULATOR ®

MYCALEX CORPORATION of AMERICA
World's Largest Manufacturer of Glass-bonded Mica Products
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continued from page 220

on loan from National Advisory Committee for Aeronautics, 1724 F St., Washington 25, D. C. Elastic properties of various binary and ternary chill-cast or sintered aluminum alloys. Nitrides of Al, Cr, Mg, Fe, V, Ti and Zr caused appreciable increase in Young's modulus. Ternary intermetallic compounds showed similar effect. Specific Young's modulus improved by additions of chromium or manganese.

ALUMINUM - COPPER - CADMIUM SHEET ALLOYS. *H. K. Hardy, Ministry of Supply, Great Britain (1952). Report N-21259, 25 pp. Available on loan from National Advisory Committee for Aeronautics, 1724 F. St., Washington 25, D. C.* Exceptional capacity for hot work. Uncoated 5 copper-0.15% cadmium alloy gave 25 tons per sq in. for 0.1% proof stress, and 30 tons per sq in. maximum stress in both transverse and longitudinal directions. Cold working before artificial aging markedly raised tensile properties of aluminum-copper alloys but reduced properties of aluminum-copper-cadmium alloys. The proof stress can drop by 3 tons per sq in., but this effect can be prevented by giving alloy short partial aging treatment at 330 to 340 F before cold working. Aluminum - copper alloys showed marked susceptibility to stress corrosion resulting from severe intercrystalline corrosion. Aluminum-copper-cadmium alloys were immune from stress corrosion and showed intercrystalline attack when sprayed with 3% salt solution.

STRESS CORROSION IN AIRCRAFT ALLOYS. *Joseph B. McAndrew and Howard T. Francis, Armour Research Foundation (1952). Report N-15503, 24 pp. Available on loan from National Advisory Committee for Aeronautics, 1724 F St., Washington 25, D. C.*

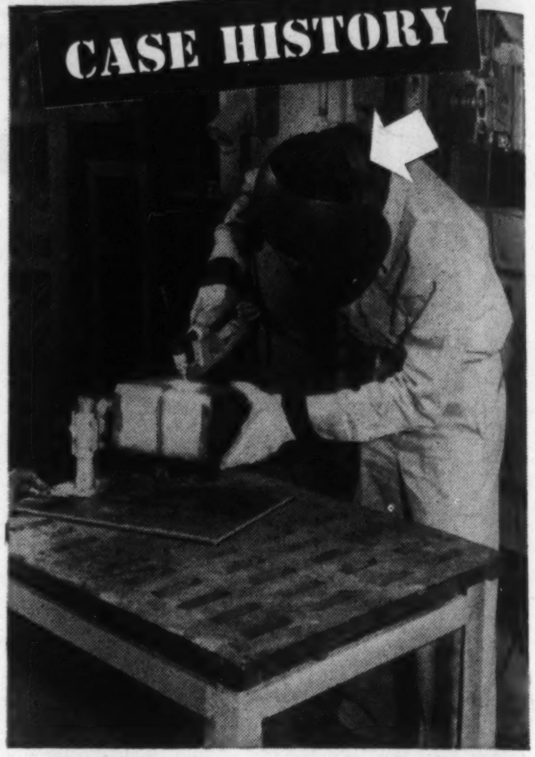
Coatings

PLATING OF ENGINE PARTS. *U. S. Naval Air Station, Pensacola, Fla. Report PB 107783, 119 pp. Available from Library of Congress, Publication Board Project, Washington 25, D. C. Microfilm $4.75, photostat $15.00.* Data on experimental plating of internal engine parts, endurance and service testing of engines with plated internal parts, cor-

(Continued on page 224)

LET SHEFFIELD SHAPE YOUR PROGRESS . . .

With fine plastic extrusions to cut cost — improve quality — speed production in unlimited industrial applications.



PROBLEM: A sweat-resistant, durable welder's helmet headband was needed.

SOLUTION: A plastic extrusion by Sheffield that defied deterioration, with greater dimensional stability and strength. Another contribution by Sheffield to progressive industry.

Mile after mile of strips . . . rods . . . tubes . . . custom contours in an infinite variety of shapes are extruded by skilled plastic technicians at Sheffield. Expert design service — scores of dies — "on the spot" special machining — prompt presentation of samples — all assure you of a plastic extrusion of unsurpassed precision for your application.

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Mr. Henry H. Van Cleef
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Phone: Main 1-8410

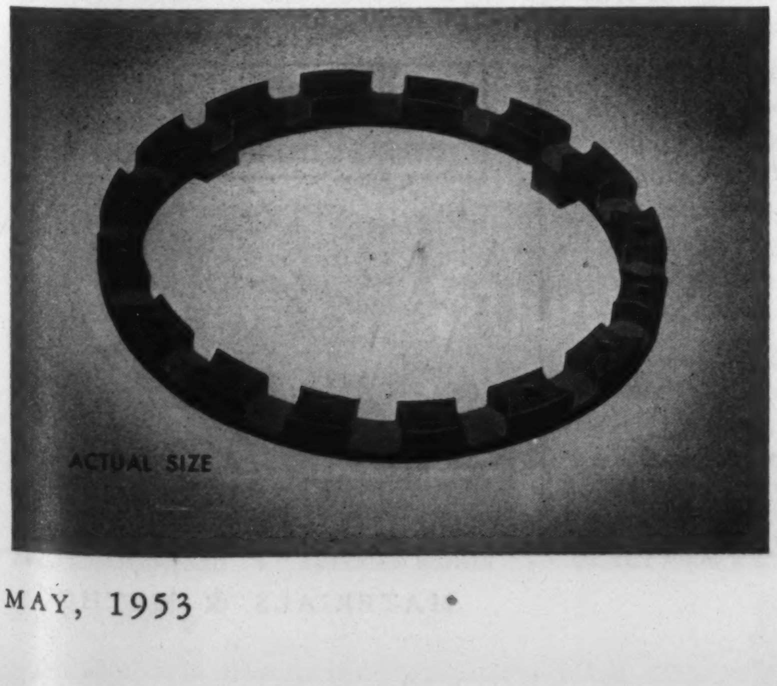
Precision casting news from Arwood

by Arwood Engineers

Another part designed for economy — the red brass Ball Bearing Retainer illustrated below.

The retainer is cast in two halves each containing its half of the bearing pocket and rivet holes. Since this part is a bearing, Arwood's engineers have maintained a true roundness and smooth flat surfaces to permit a close fit and proper operation of the assembly.

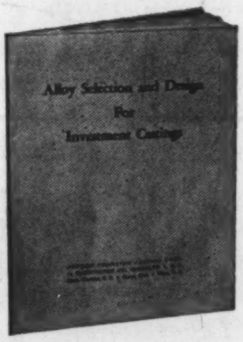
TIP TO DESIGN ENGINEERS—The part illustrated below needs no further machining after casting. The pockets, the pitch diameters of those pockets, and the rivet holes are all held to very close tolerances. In addition the exact placement of rivet holes must be obtained in order to insure the perfect alignment of rivets when assembling the unit. We have illustrated a part cast in a copper base alloy, but we also cast parts in magnesium, aluminum, carbon, stainless, and various other steels. Details are in our booklet, "A Critical Survey of Investment Castings."



ART STOLKEY

Art Stolkey, Arwood's representative in Michigan, was one of the first investment casting foundry representatives in the area and has witnessed and helped the amazing growth of interest in the process in his territory. Today most of the engineers in Michigan's industries realize the importance of the investment casting process and are evaluating its use.

Like all Arwood representatives, Mr. Stolkey's experience enables him to help engineers and industrial buyers decide which difficult jobs can be produced quickly, accurately, and more economically by the Arwood Precision Casting method.

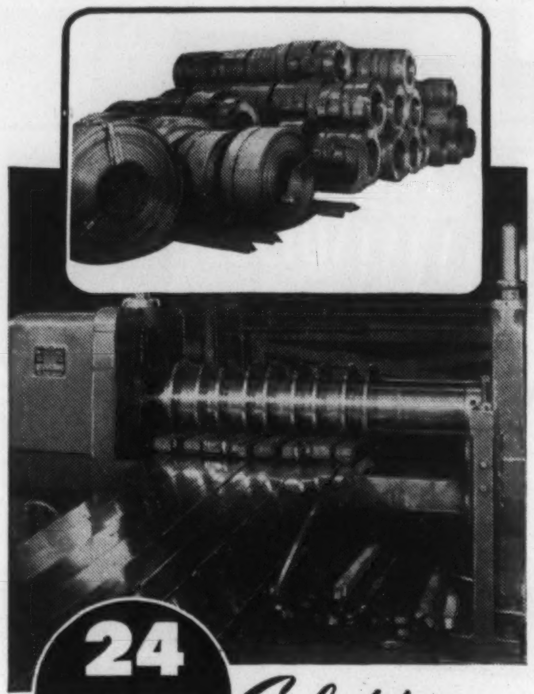


For more complete information write for our booklet, "Alloy Selection and Design for Investment Castings."

☆ ☆ ☆

An important new book—"Investment Casting for Engineers"—has just been published by Reinhold Publishing Co., New York. It is highly recommended reading for all design engineers.

ARWOOD
PRECISION CASTING CORP.
74 WASHINGTON STREET • BROOKLYN 1, N. Y.
Plants: Brooklyn, N. Y., Groton, Conn., Tilton, N. H.



24 HOUR *Slitting Service!*

If you operate a slitter of your own, you may always enjoy this kind of service. Think what a blessing it is to be able to meet expected and unexpected needs for slit strands on such short notice—how greatly it simplifies production planning—how it eliminates production bottlenecks and minimizes strip inventories.

Then, too, when you buy strip in standard widths, your strip supply sources are more numerous. You can buy wherever you get the best delivery, price, and quality.

Slitting service now may cost you anywhere from $10.00 to $100.00 or more per ton. Even if your needs were only 50 tons per month, at an average of $20.00 per ton for slitting, the cost per year would be $12,000—an amount which alone may be more than sufficient to make a Yoder slitter highly profitable.

The Yoder Slitter Book (sent on request) analyzes and discusses the economics as well as the mechanics of slitter operation. Yoder engineers will be glad to study your needs and submit recommendations as to kind, size, and cost of suitable slitting equipment.

THE YODER COMPANY
5546 Walworth Avenue • Cleveland 2, Ohio

Rotary Gang SLITTERS

ENGINEERING YODER MANUFACTURING

continued from page 222

rosion testing of engines with plated internal parts by unprotected outdoor storage, and production plating of internal engine parts. Coatings of 0.0001-in. cadmium-tin alloy will effectively prevent corrosion of engine parts, even under adverse operating and storage conditions, during one or more major overhaul periods.

FORMULATION AND DEVELOPMENT OF REFRACTORY CERAMIC BASE COATS FOR INGOT IRON AND ALLOY METALS. *Univ. of Illinois (1949). Report PB 107811, 15 pp. Available from Library of Congress, Publication Board Project, Washington 25, D. C. Microfilm $1.75, photostat $2.50.*

INVESTIGATION OF GASES EVOLVED DURING FIRING OF VITREOUS COATINGS ON STEEL. *Dwight G. Moors and Mary A. Mason, National Bureau of Standards (1953). NACA TN 2865, 34 pp. Available from National Advisory Committee for Aeronautics, 1724 F St., Washington 25, D. C.* Gases are carbon monoxide, carbon dioxide and hydrogen. Carbon gases cause primary boil. Hydrogen diffuses into coating as firing continues but is expelled on fast cooling, causing bubbles to form at interface of coating. Bubble structure in normally fired enamel due to impurities in clay addition.

THE EFFECT OF STOVE ENAMELING TEMPERATURES ON ALUMINUM ALLOYS. *G. Meikle and J. Thompson, Royal Aircraft Establishment, Great Britain (1952). Report N-21034, 9 pp. Available on loan from National Advisory Committee for Aeronautics, 1724 F St., Washington 25, D. C.* Effects of heating D.T.D. 603 type alloy at 250, 300 and 330 F—temperatures liable to be used for stove enameling or for "curing" synthetic resin adhesives.

FUNGICIDES FOR USE IN PAINTS. PART I. TEST METHODS FOR EVALUATING PAINT FUNGICIDES. *Army Engineer Research and Development Laboratories. Report PB 111061. Available from Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C. Mimeo $.75.*

FUNGICIDES FOR USE IN PAINTS. PART II. EVALUATION OF PAINT FUNGICIDES. *Army Engineer Research and Development Laboratories. Report PB 111062. Available*

(Continued on page 226)

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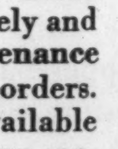

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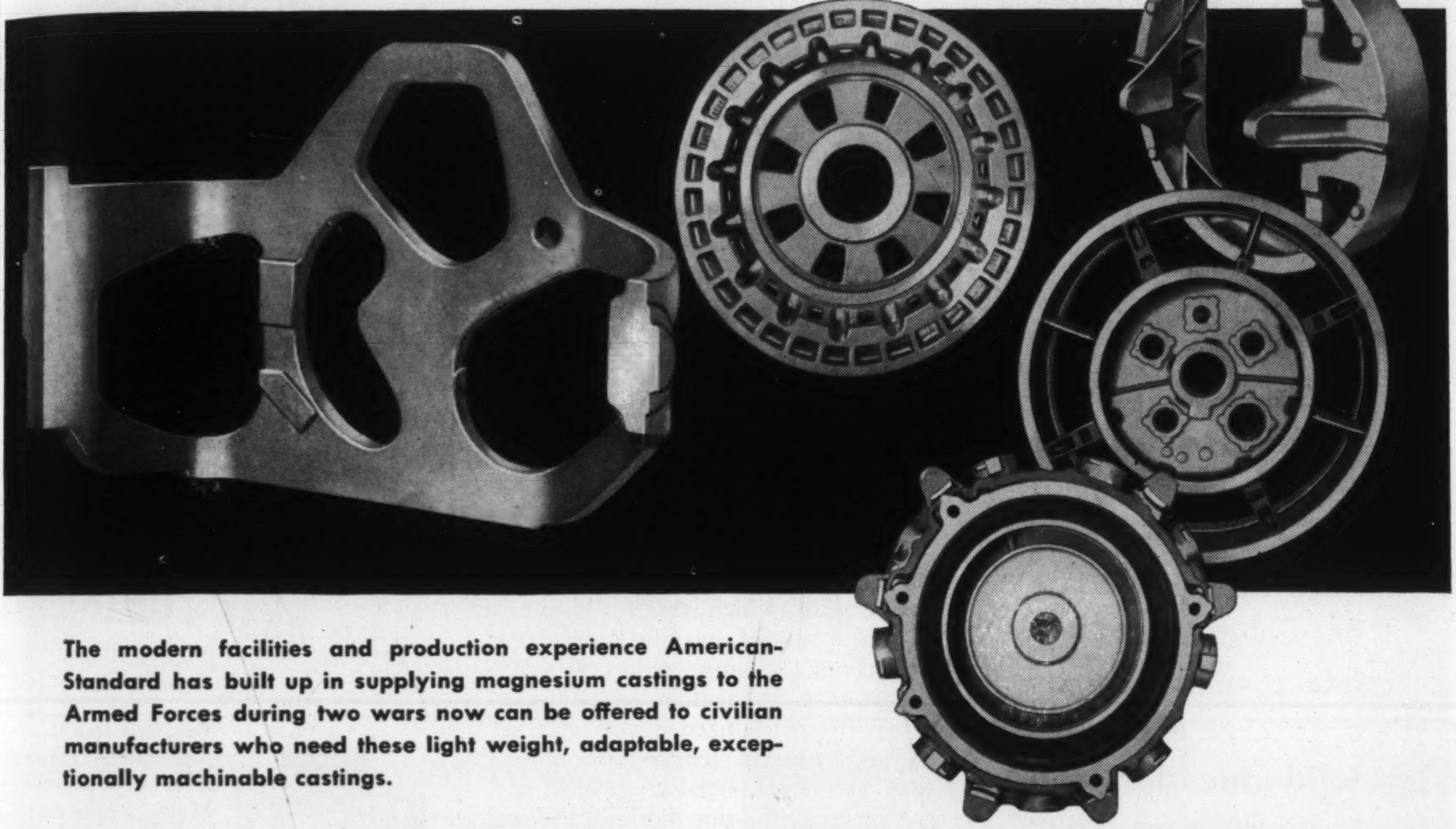

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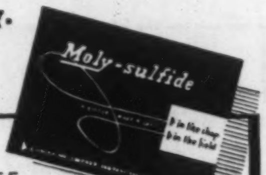

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continued from page 224

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Others

A LINEAR TIME - TEMPERATURE RELATION FOR EXTRAPOLATION OF CREEP AND STRESS-RUPTURE DATA. *S. S. Manson and A. M. Haferd (1953). NACA TN 2890, 49 pp. Available from National Advisory Committee for Aeronautics, 1724 F St., Washington 25, D. C.*

EFFECT OF PROCESSING VARIABLES ON THE TRANSITION TEMPERATURE, STRENGHT AND DUCTILITY OF HIGH-PURITY, SINTERED, WROUGHT MOLYBDENUM METAL. *Kenneth C. Dike and Roger A. Long (1953). NACA TN 2915, 26 pp. Available from National Advisory Committee for Aeronautics, 1724 F St., Washington 25, D. C.* Transition temperature range near room temperature, which varies according to the amount of swaging reduction; increasing swaging reduction decreases the transition temperature range. Recrystallized metal has a higher transition temperature range than as-swaged metal, regardless of the amount of prior working. Ultimate tensile strengths of as-swaged, stress-relieved or recrystallized metal are affected by varying amounts of working from 35 to 99% swaging reduction, but the differential is not large. Ductility of as-swaged metal at room temperature increases with increased working; however, when stress-relieved, the ductility does not vary with working. Recrystallized metal has good ductility above the transition range provided that prior working is greater than about 50%.

INVESTIGATIONS INTO GLUES AND GLUING, PROGRESS REPORT 72—NOVEMBER 1952. THE BONDING OF PRESERVATIVE TREATED VENEERS WITH PHENOLIC RESIN. *R. A. G. Knight, L. S. Doman and G. E. Soane, Forest Products Research Laboratory, Great Britain. Report N-20964, 6 pp. Available on loan from National Advisory Committee for Aeronautics, 1724 F St., Washington, 25, D. C.* Tests on phenolic-bonded plywood with preservatives applied to the individual veneers before being bonded together.

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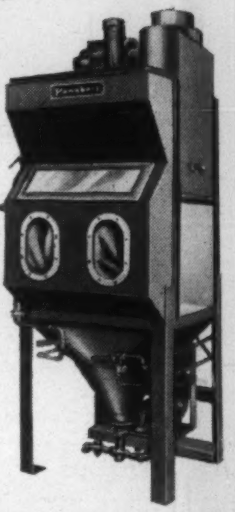

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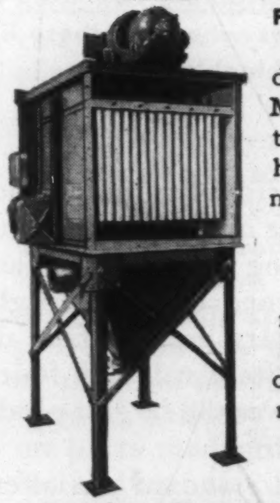

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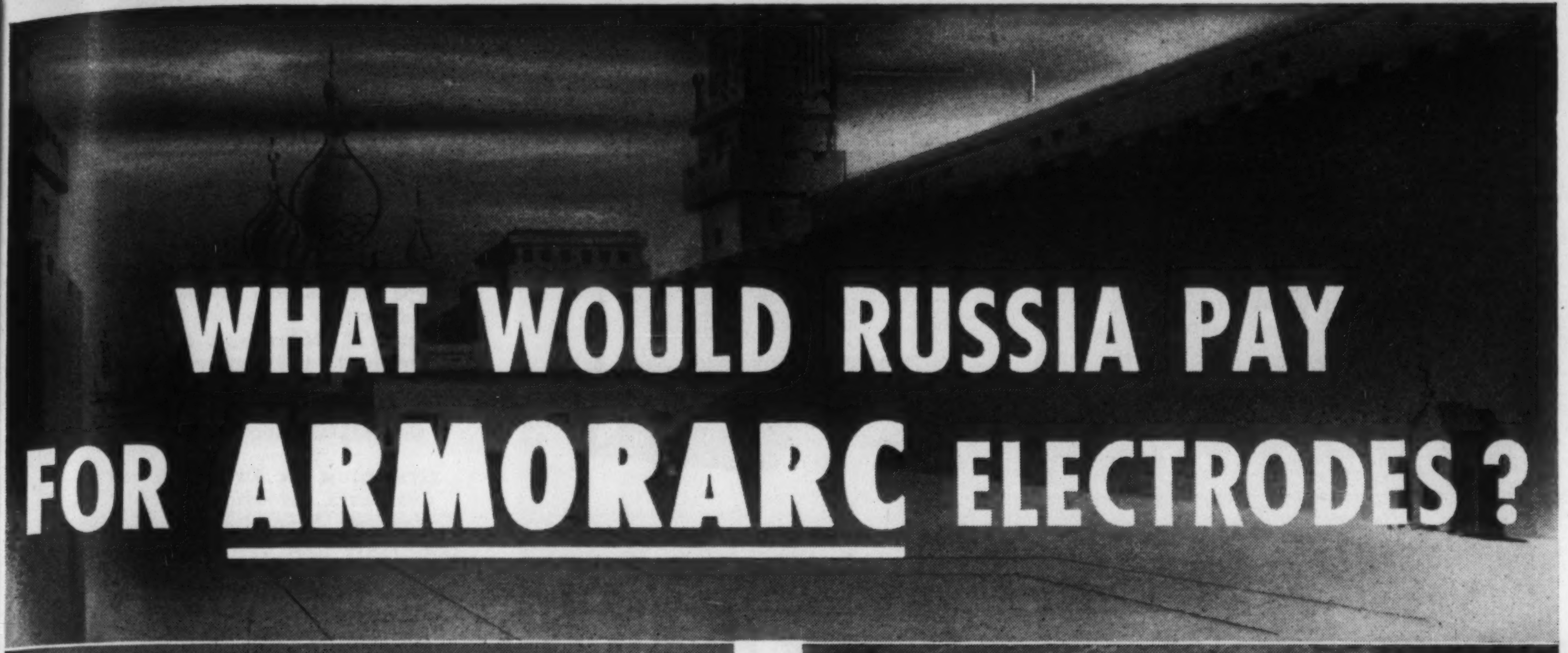

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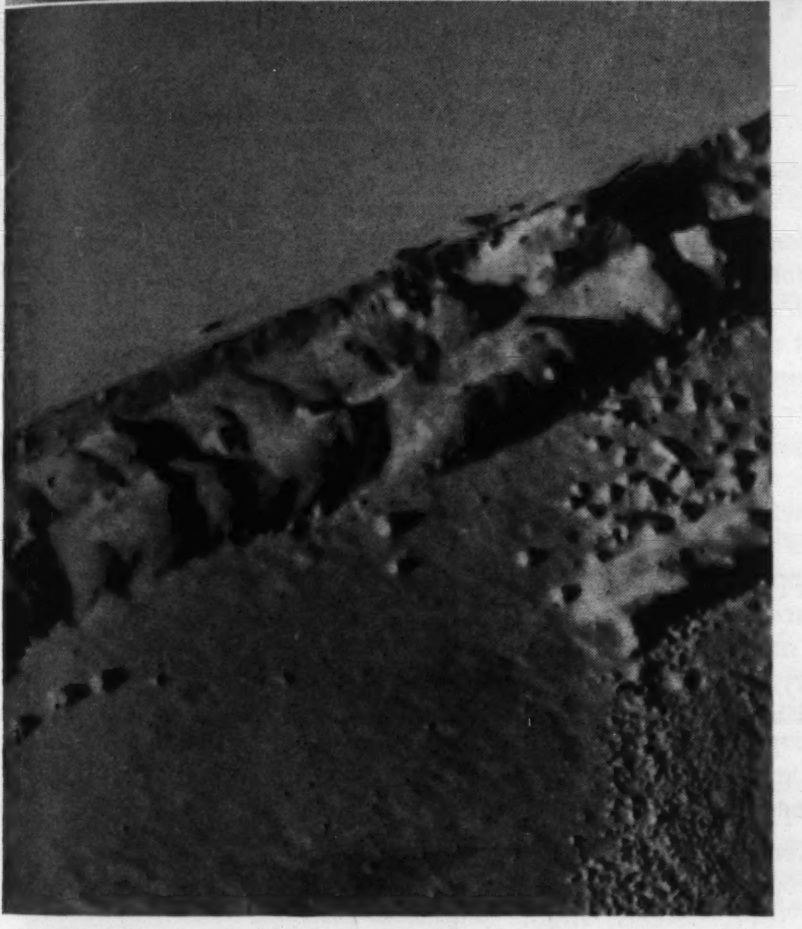
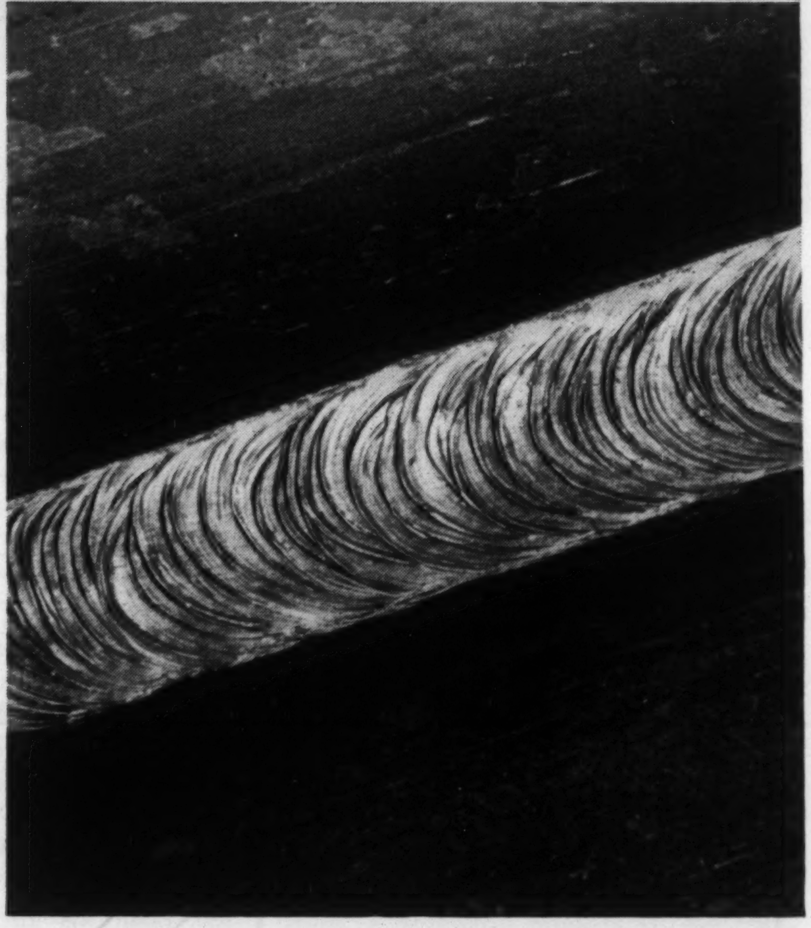


Photo courtesy H. C. Phelps, Welding Engineer

THE IRON CURTAIN WAY • Unretouched photo of welded joint on Russian T-34 tank, captured in Korea, now a museum piece at Aberdeen Proving Grounds of the Ordnance Corps. Joint appears welded over and over again...weld spatter is everywhere . . . typical of Red Communism's vaunted "efficiency."



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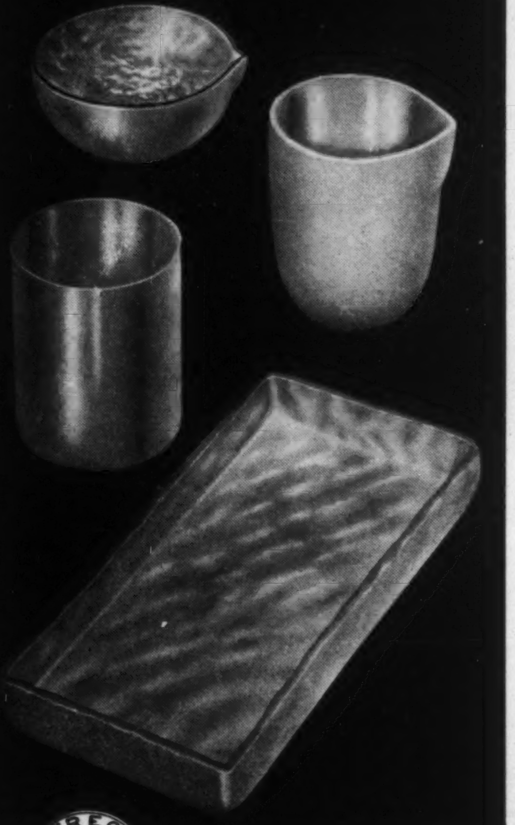

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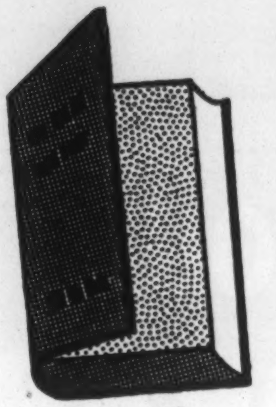

BOOK REVIEWS

Metallurgy

ENGINEERING METALLURGY. *By A. P. Gwiazdowski. Published by C. C. Nelson Publishing Co., Appleton, Wis., 1950. Cloth, 6 by 9 in., 248 pp. Price $4.00.*

Here is a text designed to give the student, purchasing agent, production executive, and engineer, basic metallurgical information about the nature and characteristics of the commercially important metallic elements and their alloys. Data dealing with chemical analysis, application, and heat treatments of various tool steels were obtained from metallurgical departments of industry.

Chapters deal with such topics as: "Metals and Their Properties"; "Structures and Composition of Ferrous Alloys"; "The Static Properties of Metallic Materials"; "The Metallic Elements, Properties, Alloy Compositions and Uses"; "Steels, Ingot and Wrought Irons"; "Rolling Processes"; "Applications of SAE Steels"; "Heat Treatment of Ferrous Alloys"; "High-Speed and Commercial Tool Steels"; "Corrosion and Heat Resisting Steels"; "Processing of Rolled Steels"; "Cast-Ferrous Alloys"; "Cast Steels"; "Light Nonferrous Alloys"; "Heavy Nonferrous Alloys"; "Bearing Metals"; and "Finished Steel Products by States".

The author, in preparing the text, holds to the following objectives: clear and concise definitions; principles; selection of materials; selection of heat treatments; and engineering specifications.

Numerous tables and illustrations supplement the text.

Other New Books

PRESSWORK AND PRESSES. *By J. A. Grainger. The Machinery Publishing Co., Ltd., Brighton 1, England, 1952. Cloth, 8¾ by 11¼ in., 260 pp. Price $7.75.* This book is designed to provide all concerned with the production of sheet-metal presswork with a reasonable account of the problems encountered in press-tool development, design and operation, and to indicate practical methods of overcoming them. After dealing first with simple operations, the author progresses through the whole range of modern press-tool operations, indicating the type of tool for a given job, how it is used, and the type of machine on which it should be employed. Many types of modern presses are illustrated, their operational features dealt with, and their relative merits and shortcomings discussed.

SYMPOSIUM ON DETERMINATION OF ELASTIC CONSTANTS. *American Society for Testing Materials, Philadelphia 3, Pa., 1952. Paper, 6 by 9 in., 110 pp. Price $2.00.* The papers and discussions in this Symposium were presented at the 17th session of the 55th Annual Meeting of the ASTM held on June 25, 1952. The Symposium was sponsored by the Task Group on Elastic Constants of Committee E-1 on Methods of Testing. The titles and authors of the papers are as follows: "Report on ASTM Task Group for Determination of Elastic Constants"—Walter Ramberg; "The Influence of Temperature on the Elastic Constants of Some Commercial Steels"—F. Garofalo, P. R. Malenock, G. V. Smith; "Methods for Determining the Elastic Constants of Nonmetallic Materials"—E. W. Kuenzi; "Dynamic Methods of Determining the Elastic Constants and Their Temperature Variation in Metals"—M. E. Fine; "An Evaluation of Several Static and Dynamic Methods for Determining Elastic Moduli"—John T. Richards.

RULES FOR WELDING PIPING IN MARINE CONSTRUCTION — CARBON STEELS. *Published by American Welding Society, New York 18, N. Y., 1953. Paper, 6 by 9 in., 12 pp. Price 50¢.* This revision of the 1948 edition includes changes and clarifications of the requirements agreed upon by the Enforcement Authorities in the Shipbuilding industry: American Bureau of Shipping; U. S. Navy Dept.; and U. S. Coast Guard. The new rules include typical joint design details for splices, branches and nipples. An x-ray standard for evaluation of weld quality has been added; and specific electrode requirements as to classification and sizes for different positions of welding are now included, as is an expanded description of weld quality and weld defects.

SIMPLE BLUE PRINT READING WITH SPECIFIC REFERENCE TO WELDING AND WELDING SYMBOLS. *Published by the Lincoln Electric Co., Cleveland 17, Ohio, 1953. Cloth, 6 by 9 in., 207 pp. Price $1.00.* Here is a new and enlarged edition of a book for welders and others engaged in the fabrication of machinery. It is intended as a guide to a clear understanding of blue prints and how to use them in mechanical fabrication and construction. Included in this 4th edition are over 200 illustrations; step-by-step explanations of how to read blue prints; complete discussion of welding symbols and where they are used.

MECHANICS OF MATERIALS. *By Seibert Fairman and Chester S. Cutshall. Published by John Wiley & Sons, Inc., New York 16, N. Y., 1953. Cloth, 6 by 9 in., 420 pp. Price $5.75.* This text is designed to provide a sound understanding of the elements of mechanics of materials and a thorough training in the use of basic principles, while keeping the material at the level of the average engineering student. Outstanding features of the book are: numerous illustrative examples, completely solved, to aid the student in learning how to apply the principles; a large selection of problems to be solved by the student, over 700. Some of these problems are grouped at the end of the specific articles on which they are based—others are grouped at the ends of chapters and are often more general in nature or of a higher order of difficulty; a treatment of columns designed to give the student a better understanding of the basic theory and its connection to the development of the empirical formulas used in practical design.

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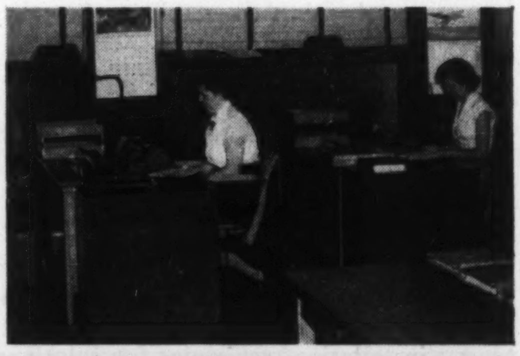

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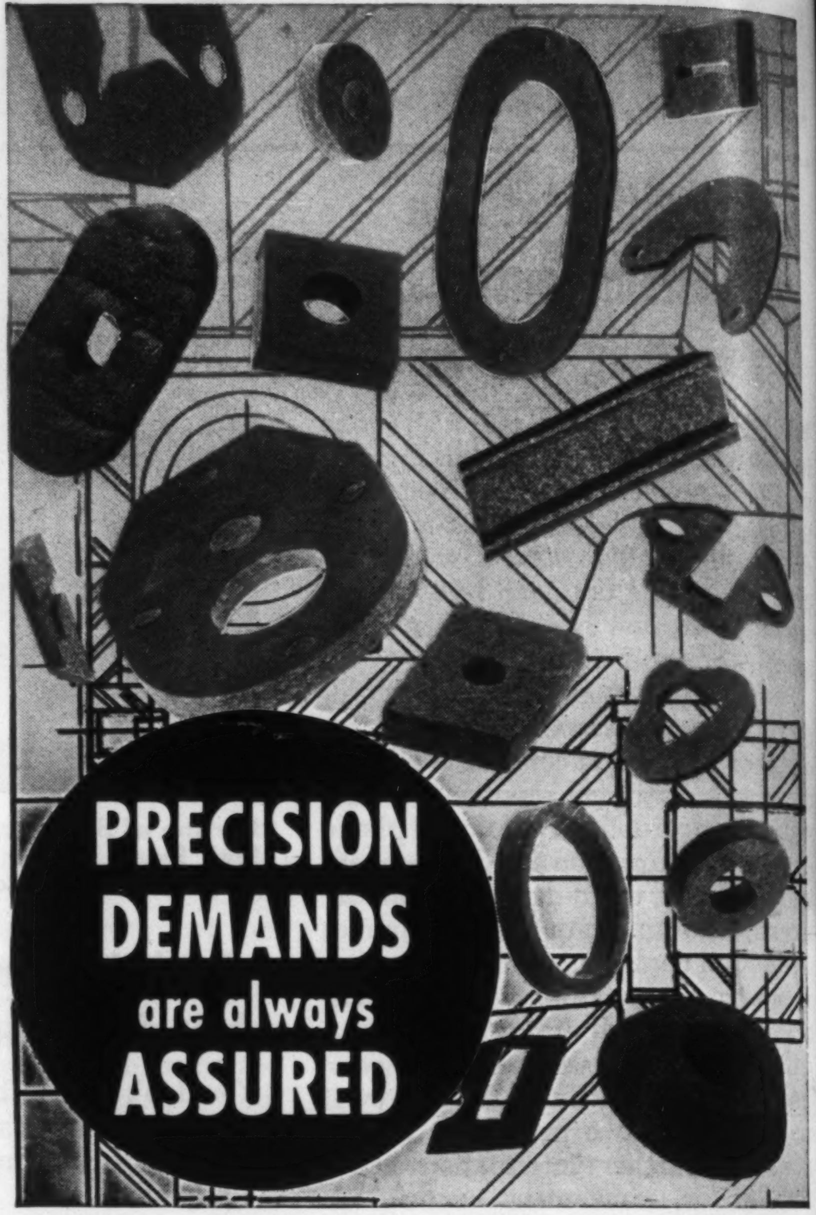

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